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NAVY DIVER TOOLS, DEVELOPMENT AND EVALUATION.(U)

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NAVY DIVER TOOLS, DEVELOPMENT AND EVALUATION

F. B. BARRETT

NAVAL COASTAL SYSTEMS LABORATORY
NCSL
PANAMA CITY, FLORIDA 32407

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NAVAL COASTAL SYSTEMS LABORATORY

PANAMA CITY, FLORIDA 32401

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ADMINISTRATIVE INFORMATION

The report and the diver tools development and evaluation upon which it is based were sponsored by the Naval Sea Systems Command Supervisor of Diving and Director of Ocean Engineering.

Released by
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Technical Director

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State-of-the-art studies	Hydraulic equipment	Working diver
Evaluation	Identifiers:	Diver hand held tools
Tests	Hand held power tools	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The history and current status in the development and evaluation of Navy diver tools is discussed in detail. The purposes of the report are: (1) to present all available data concerned with the suitability of selected tools for Naval fleet use, (2) to indicate the requirements for additional evaluation tests and (3) to present data useful to designers and users of underwater tools.

SUMMARY

The purpose of the report is to present available data concerned with the suitability of selected Navy diver tools for Fleet use. The detailed information presented will be of use in obtaining authorization for Navy use of the tools and as background data for designers and evaluators of underwater tools.

The history and current status in the development of Navy diver tools is presented. Specific evaluations and recommendations of the divers participating in the evaluation are listed. A list of completed tool modifications, drawings, and manuals is included.

The following tools have been subjected to extensive evaluation.

Hydraulic Power Supply, NAVSEA, Model II
Hydraulic Grinder, Stanley, Model GR24
Hydraulic Impact Wrench, Stanley, Model 1W06
Hydraulic Impact Wrench, Stanley, Model 1W13
Sump/Jetting Pump, Stanley, Model 2250H-0C
Diver Operated Pump, Enerpac/NCSL P80 (Modified)
Barstock Cutter, H. K. Porter, Model 36274
Wire Rope Cutter, H. K. Porter, Model 36262
Lift Bag, SUPDIV, 750 lb.

The tools listed below have been subjected to preliminary evaluation at NCSL. Fleet evaluation and data collection has not been accomplished.

Hydraulic Abrasive Wheel Saw, NCSL
Come-a-Long, Griphoist, Model TU28H and TU17H
Hurst Rescue Tool, 6 ton capacity, Hurst Performance
Flow Divider, Fluid Controls/NCSL
Single Acting Jack Rams, Enerpac, Model RC 106 and RC 1010
Hydraulic Pull Cylinder, Misc. Suppliers
Intensifier, Hydraulic, NCSL
Hydraulic Portable Power Source, NCSL
Rock Drill Kit, Pneumatic Tool Sales/NCSL
Torque Limiter, 4X Corporation

These tools should be procured and issued to Navy diving groups for use and additional evaluation as was done with the tools issued in the Navy

Diver Tool Kits. The Navy diving groups should be required to complete such evaluation without delay. NCSL should prepare, administer, and evaluate questionnaires prepared for the test and evaluation phase.

All tools listed in both of the before listed groups should undergo cold water testing.

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SECTION 1

INTRODUCTION

This report summarizes the development of pneumatic, hydraulic, and operator powered (such as a hydraulic jack) Navy diver tools and discusses their evaluation. The primary purpose of the report is to present available data concerned with the suitability of selected Navy diver tools for Fleet use. The end objective is to obtain authorization for Fleet procurement and use of the tools. It is important to document the lessons learned from extensive Fleet and school use to establish the utility of the tools for underwater work and to determine required modifications.

Detailed evaluation data and discussions are limited to tools comprising power tool kits currently located within the Fleet.

The NAVSEA Director of Ocean Engineering and the Supervisor of Diving have sponsored an ongoing program to increase the capability of the Navy working diver. The basic approach was to determine the diver tool requirements and then meet them using industrial state-of-the-art hardware. Modifications and additions have been made with the help of Fleet and NAVSEA personnel.

This report is divided into nine major sections: (1) Introduction, which includes tool development background information and a survey of related work, (2) Requirements for diver tools, (3) Diver tools requiring authorization for Navy use, (4) Diver tool evaluations, (5) Tool problems, recommendations, and action summary, (6) Completed tool modifications, (7) Drawings, manuals, and components list status, (8) Conclusions and recommendations, and (9) Summaries of Referenced reports.

The Navy involvement in diver tool test and development began at the Naval Civil Engineering Laboratory, Port Hueneme, California, in 1967. At that time, there were no known reports of diver performance using hand tools and power tools under controlled conditions. Consequently, a comparative study was made using hand tools and pneumatic tools on land, in a test tank, and in the ocean at a depth of 50 feet (Reference 1).

The early tests and discussions with commercial diving personnel verified the general increased effectiveness of diver tools in contrast

to hand tools while highlighting some of the limitations of pneumatic power tools. Among the limitations were problems of maintenance, excessive noise, pressure/depth limitations, and obstruction of diver vision by exhaust bubbles.

Tests soon followed which permitted comparison of pneumatic and hydraulic impact wrenches. The tests included a variety of commercially available hydraulic tools, a cryogenic power module, an electrohydraulic power supply, and a diesel-hydraulic supply unit (Reference 2). Both pneumatic and hydraulic tools proved reliable; however, the pneumatic tools were much more time consuming to maintain. Generally, it was concluded that pneumatic tools lose their effectiveness below 120 feet. The importance of diver training for operational effectiveness and safety was further verified.

The determination of work functions most important in underwater work, was basic to the planning for a diver tool development program. Work functions were compiled by reviewing 16 past salvage operations and by related discussions with experienced salvors (Reference 3). The results indicated seven work functions which were compatible with underwater tools.

Extension of the U.S. Navy's underwater tool salvage capability required improvement of diver-operated tools and their equipment. This work was continued at NCEL (Reference 4). The diver-powered tools included hydraulic pumps, pull cylinders, and cutters. Evaluations were also made of several open centered hydraulic tools powered by diesel-driven power units. The effectiveness of various diver hand tools, explosively actuated tools, and power tools was well demonstrated during the SEALAB III salvage team trials conducted offshore from Port Hueneme, California (Reference 5). In 1971, the diver tool tests were expanded to include evaluations of two self-contained submersible power supplies (Reference 6). These were a cryogenic power module and an electrohydraulic power unit. The tests established that both were effective as submersible power sources.

A study of design criteria for hydraulic tool power sources was completed at NCEL in 1973 (Reference 7). The Navy Supervisor of Salvage and Supervisor of Diving authorized the assembly of diver tool sets at NCEL, Port Hueneme. The objective was to provide tools suitable for preliminary issue to select Fleet units. A detailed description of the power supply and tools is contained in Reference 8.

Shortly after the development and issue of the first Fleet tool sets, the decision was made to consolidate NAVSEA diver related development work at NCSL, Panama City, Florida. Consequently, the remainder of the diver tool development and evaluation described in this report has been accomplished at NCSL.

Work continued at NCSL to improve the Navy diver tool kit power supply and components. Trips to Fleet units were made both to provide instruction and to establish communications for user comments concerning the tools and the need for additional tools or equipment. The tool kits have been received with enthusiasm. A manual describing the operation and maintenance of the Navy tool kit, power supply, and tool components is nearing completion.

A close liaison with commercial diving organizations has been maintained throughout the diver tool program. There is a great similarity in the Navy and commercial diver tool requirements and much the same type of tools are used. The exchange of information has been mutually beneficial.

The U.S. Navy Supervisor of Salvage and Diving sponsored an Underwater Ship Husbandry Workshop at NCSL in January 1975. The major objective of the workshop was to familiarize the participants with the scope and nature of underwater ship husbandry work, document state-of-the-art developments in major task areas, and suggest improvements in technology and management (Reference 9).

SECTION 2

REQUIREMENTS FOR DIVER TOOLS

A diver's effectiveness in performing useful underwater work is very closely related to the tools he has at his command. In commercial salvage and construction diving, off-the-shelf pneumatic and hydraulic tools are often used to enable the diver to get the job done faster or more effectively. In some cases the tools are absolutely essential. There is a parallel need in the Navy but it is much more difficult for fleet personnel to procure such off-the-shelf items for several reasons, including lack of service approval. The Navy Supervisor of Salvage/Supervisor of Diving clearly recognized this need and has supported the development, testing, procurement, and issue of diver tool kits to Fleet activities. Discussions and conferences with Navy fleet diving personnel have definitely verified the need and the value of the tool kits.

Preliminary to the development of diver tool kits, the Naval Civil Engineering Laboratory conducted a study to determine underwater work functions required in salvage (Reference 3). Sixteen representative salvage operations completed between 1915 and 1971 were reviewed. Both ship and submarine salvage operations are included. The identified work functions are listed in Table 2-1.

TABLE 2-1

UNDERWATER WORK FUNCTIONS IN SALVAGE OPERATIONS

Task	Relative Frequency of Functions		
	Ship Salvage	Submarine Salvage	Deep Salvage Operations*
Drilling	3	2	-
Tapping	2	2	-
Bolting	2	7	-
Mechanical Cutting	3	3	3
Torch Cutting	4	5	-
Explosive Cutting	2	1	-
Welding	1	-	-
Power Velocity Attachments	1	-	-
Connecting Threaded Fittings	4	8	-
Operating Small Valves	3	8	-
Rigging and Handling	4	8	3
Grappling	-	-	2
Placing Concrete	3	4	-
Tunneling/Excavating	4	5	-

*Primarily submersible operations

Salvage conferences were held with two experienced salvors. The underwater work functions identified from the review of past salvage operations were discussed to determine their difficulty and importance in future salvage operations. The first conference was held with Mr. Earl Lawrence who was NAVSHIP Salvage Master in recent years and was previously Rigger/Diver Supervisor of Diving Operations at the Puget Sound Naval Shipyard. The second conference was held with Mr. Bill Badders who is presently a salvage consultant. He has had a distinguished career as a Senior Master Diver in the Navy and was Salvage Master/Master Diver for the Panama Canal for over 45 years.

Based on the conferences, a numerical rating was assigned to each work function to reflect its utility in future underwater salvage operations. The rating values were:

Very useful	6
Useful or potentially useful	4
Questionable usefulness	2
No use	0

The rated future usefulness of the underwater work functions follows as shown in Table 2-2.

TABLE 2-2

RATED USEFULNESS OF UNDERWATER WORK FUNCTIONS

Function	Relative Numerical Rating		
	Lawrence Conference	Badders Conference	Mean Rating
Drilling	0	2	1
Tapping	0	2	1
Bolting	6	6	6
Mechanical Cutting	4	4	4
Torch Cutting	6	6	6
Explosive Cutting	4	4	4
Welding	2	0	1
Velocity Power Attachments	4	6	5
Connecting Threaded Fittings	2	4	3
Operating Small Valves	0	2	1
Rigging and Load Handling	6	6	6
Grappling	6	4	5
Placing Concrete	0	2	1
Tunneling/Excavating	4	4	4

SHIP HUSBANDRY WORKSHOP

An underwater ship husbandry workshop was sponsored by the U.S. Navy Supervisor of Diving. The conference took place at NCSL during January 1975 (Reference 9). The workshop was intended to familiarize participants with the scope and nature of underwater ship husbandry work; document state-of-the-art in major task areas; and suggest improvements in technology and management. Shipyard problems, diving, underwater tools, and underwater ship husbandry relative to dry docking were discussed. Only those findings or conclusions having a direct bearing on underwater tools are discussed.

The current demand for power tools was concluded to justify the 8 years of R&D that have been directed by SUPDIVE. The demand level was interpreted as the onset of a more formal program, requiring fleet

and laboratory input to define operational requirements for further tool development.

The increasing importance of underwater hull cleaning including propeller and sonar dome cleaning was emphasized by several attendees.

Activities participating in the Ship Husbandry Workshop were asked to quantify certain aspects of their work by completing a questionnaire. Average responses from 24 activities are shown in Table 2-3.

Because one days activity may involve repair of several items, or inspection of several items, the total within each category need not be exactly 100 percent.

Three of the 24 activities were primarily engaged in research, rather than operational activities. Among the 21 operational activities, ship husbandry work occupied 88 percent of all dives.

Inspection was performed on 47 percent of ship-husbandry-related dives, repair on 39 percent, and maintenance on 22 percent.

Blanking hull openings and sea chests is the most common job, both for repair and maintenance, and hand tools are used about two-thirds of the time in each area. Other time consuming repair jobs are shaft seal repairs, work in ballast tanks, and dome and transducer repairs. Dome scrubbing, drydock preparation, and zinc replacement are significant maintenance tasks from the time spent point of view.

Inspections involve all important underwater hull features more or less equally. Visual inspections (no voice or TV) are most common; voice only is used about one-third of the time, and TV is used about one-quarter of the time.

The participants of the Ship Husbandry Workshop also completed an Opinion Summary. Twenty-six forms from operational activities were received and three from research activities.

Twenty-four of the 26 operational activity responses indicated on the first question that new tools would be of value to them. The list of tools desired by these activities was, in order of frequency:

1. Hydraulic impact wrench - for removing and replacing zincs, gratings and blank flanges for screw changes, for ballast tank work, for drilling and tapping, and for fairwater and rope guard work.

2. Hydraulic grinder - for removing weld beads, bolt heads, and broken studs, for surface preparation prior to painting or welding, for cutting wire rope and for propeller grooming.

TABLE 2-3

BREAKDOWN OF DIVING JOBS BY TASK AND TOOL
(Sheet 1 of 2)

		Average Response
1. What percent of all dives at your activity relate to repair, maintenance or inspection of ships	(78%)	0 10 20 30 40 50 60 70 80 90 100
2. Of these ship husbandry related dives, what percent relate to:		
a) Repair	(39%)	0 10 20 30 40 50 60 70 80 90 100
b) Maintenance	(22%)	0 10 20 30 40 50 60 70 80 90 100
c) Inspection	(47%)	0 10 20 30 40 50 60 70 80 90 100
3. What percentage of your repair jobs involve:		
a) Ropeguards, fairwaters, dunce caps	(9.6%)	0 10 20 30 40 50 60 70 80 90 100
b) Screw changes	(7.5%)	0 10 20 30 40 50 60 70 80 90 100
c) Rudders, control planes	(8.3%)	0 10 20 30 40 50 60 70 80 90 100
d) Shaft seals	(12%)	0 10 20 30 40 50 60 70 80 90 100
e) Hull openings, sea chests	(34%)	0 10 20 30 40 50 60 70 80 90 100
f) Ballast tanks	(11%)	0 10 20 30 40 50 60 70 80 90 100
g) Domes, transducers	(19%)	0 10 20 30 40 50 60 70 80 90 100
h) Anchors	(4.6%)	0 10 20 30 40 50 60 70 80 90 100
i) Paint coatings	(1.7%)	0 10 20 30 40 50 60 70 80 90 100
j) Other	(10%)	0 10 20 30 40 50 60 70 80 90 100
4. In doing repair jobs, what percentage of time do you use:		
a) Pneumatic tools	(17%)	0 10 20 30 40 50 60 70 80 90 100
b) Hydraulic tools	(7.5%)	0 10 20 30 40 50 60 70 80 90 100
c) Hand tools	(67%)	0 10 20 30 40 50 60 70 80 90 100
d) Welding/cutting	(4.2%)	0 10 20 30 40 50 60 70 80 90 100
e) Paints/adhesives	(2.5%	0 10 20 30 40 50 60 70 80 90 100
f) Other	(3.8%	0 10 20 30 40 50 60 70 80 90 100

TABLE 2-3
(Sheet 2 of 2)

5. What percent of your maintenance jobs involve:

a) Zincs	(9.0%)	0	10	20	30	40	50	60	70	80	90	100
b) Blanks	(34%)	0	10	20	30	40	50	60	70	80	90	100
c) Sea chests, pitswords hull openings (without blanking)	(14%)	0	10	20	30	40	50	60	70	80	90	100
d) Rudder, propeller, control planes	(9.0%)	0	10	20	30	40	50	60	70	80	90	100
e) Hull scrubbing	(3.5%)	0	10	20	30	40	50	60	70	80	90	100
f) Dome scrubbing	(22%)	0	10	20	30	40	50	60	70	80	90	100
g) Drydock prepration	(12%)	0	10	20	30	40	50	60	70	80	90	100
h) Other	(3.5%)	0	10	20	30	40	50	60	70	80	90	100

6. In doing maintenance jobs what percentage of time do you use

a) Pneumatic tools	(21%)	0	10	20	30	40	50	60	70	80	90	100
b) Hydraulic tools	(4.8%)	0	10	20	30	40	50	60	70	80	90	100
c) Handtools	(69%)	0	10	20	30	40	50	60	70	80	90	100
d) Welding/ cutting	(2.4%)	0	10	20	30	40	50	60	70	80	90	100
e) Paints/ adhesives	(1.0%)	0	10	20	30	40	50	60	70	80	90	100
f) Other	(2.9%)	0	10	20	30	40	50	60	70	80	90	100

7. What percent of your inspection jobs involve:

a) Hull plate	(24%)	0	10	20	30	40	50	60	70	80	90	100
b) Screws, rudders, control planes	(45%)	0	10	20	30	40	50	60	70	80	90	100
c) Sea chests, pitswords, hull openings	(41%)	0	10	20	30	40	50	60	70	80	90	100
d) Zincs	(31%)	0	10	20	30	40	50	60	70	80	90	100
e) Domes, transducers	(38%)	0	10	20	30	40	50	60	70	80	90	100
f) Other	(9.0%)	0	10	20	30	40	50	60	70	80	90	100

8. In doing inspection jobs, what percent of the time do you use

a) Visual only	(58%)	0	10	20	30	40	50	60	70	80	90	100
b) TV	(22%)	0	10	20	30	40	50	60	70	80	90	100
c) Still or movie camera	(7.6%)	0	10	20	30	40	50	60	70	80	90	100
d) Voice	(32%)	0	10	20	30	40	50	60	70	80	90	100
e) Other	(3.3%)	0	10	20	30	40	50	60	70	80	90	100

3. Hull cleaning brush.

4. Complete hydraulic tool package.

5. Underwater television.

6. Chain saw, drill press, "peanut" grinder, pilgrim nut, lift bag, x-ray, and ultrasonic inspection tools, lights, chipper, drill.

The divers felt, four to one, that ships are not designed for underwater repair and maintenance. The most frequently cited examples are:

1. Lack of identification or reference marks on underwater features.

2. Use of slotted and phillips screws instead of allen head, and excessive staking.

3. Lack of lift and positioning aids on large gratings.

4. Lack of uniformity in hull openings.

The opinions on Underwater Damage Assessment Television Systems (UDATS) were basically favorable. Only four responses indicated that negative results were obtained when shipboard personnel overused the system by telling the divers how to do their job.

In summary, the opinions basically indicated that more tools and funds are needed, that on-the-job training is the most valuable type, that ship designers are not aware of the divers peculiar capabilities and restrictions, and that UDATS is very helpful.

SECTION 3

NAVY DIVER TOOLS REQUIRING AUTHORIZATION FOR NAVY USE

Limited specification data are supplied for the major power tools and their power supplies. Data for the other tools are limited to nomenclature, model, and manufacturer.

The Diesel Hydraulic Power Source (Figure 3-1) is used for powering all of the power tool components of the kit. A detailed description of the system and the operating and maintenance instructions are contained

(Text Continued on Page 11)

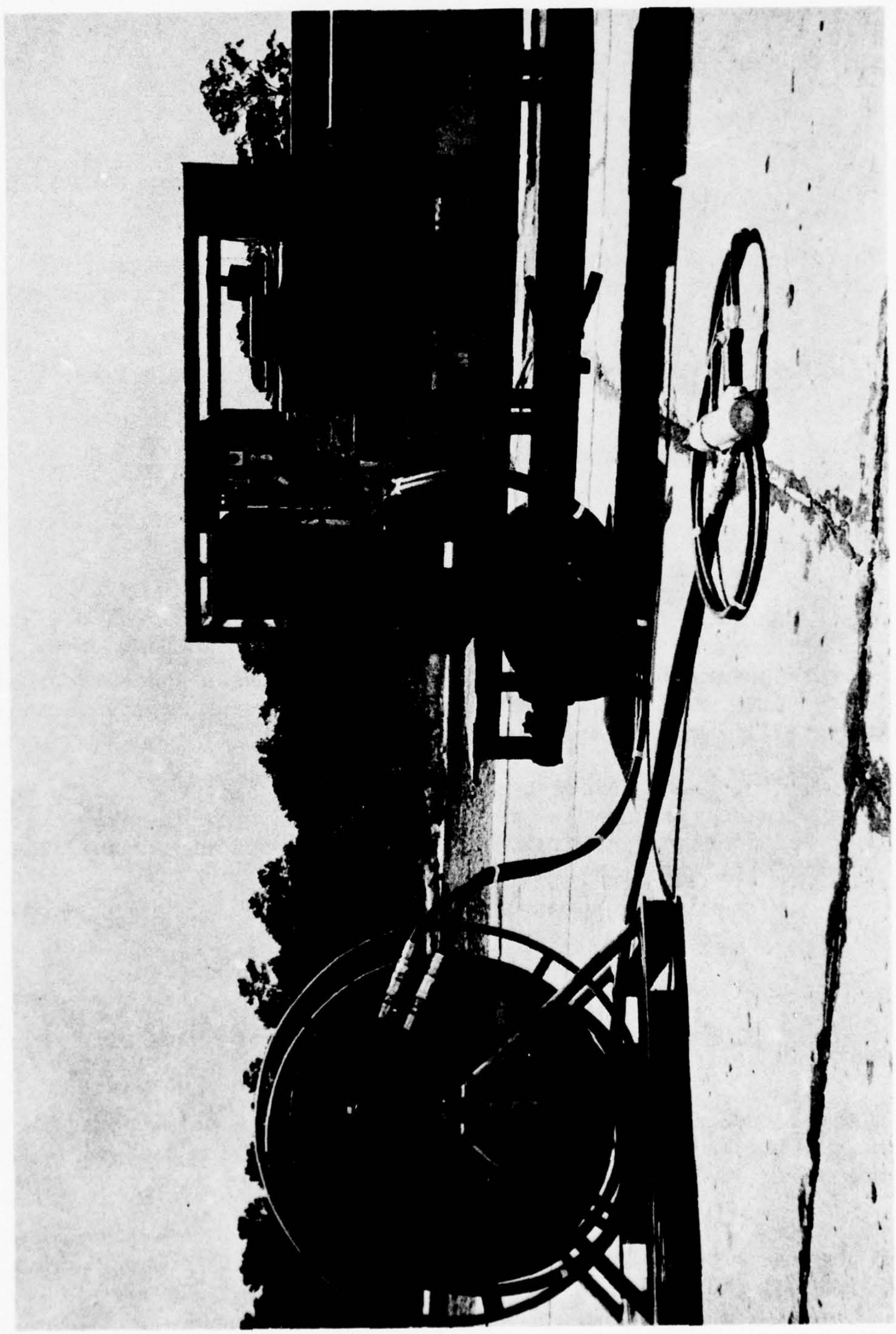

FIGURE 3-1. DIESEL HYDRAULIC POWER SUPPLY, (DHPS) NAVSEA MODEL II

in NAVSHIPS 0994-013-1010 (Reference 10). A brief description of the system follows:

TOOL: Diesel Hydraulic Power Supply

SIZE: 23" x 42" x 68"

MANUFACTURER: Naval Coastal Systems Laboratory

SHIPPING WT: 1300 lb

FUEL TANK: 5 gal

MODEL: NAVSEA Model II

HYDRAULIC RESERVOIR: 30 gal

ENGINE: ONAN Model DJC-MS
27.5 BHP @ 2400 rpm

HYDRAULIC OIL: MIL-24430

HYDRAULIC PUMP: Vickers, Variable Displacement
Model PVB 15-RDWY-30-H-W/7/8" shaft
15.7 gpm
1800 rpm, 2000 psi maximum

ACCESSORIES: Medium pressure hydraulic hose

REMARKS: Designed to power open centered hydraulic tools including: Impact Wrenches, Grinders, Sump Pumps, Cutoff Wheels, Cleaning Brushes, etc.

The constant flow hydraulic pump was replaced with a Vickers variable displacement pump, the hydraulic tubing has been simplified, a more accurate flow meter has been added, and fuel tank removal has been simplified. The hydraulic pump is shown in Figure 3-2 and the flow meter in Figure 3-3.

No recent modifications have been made to the hydraulic grinder (Figure 3-4).

TOOL: Grinder

OUTPUT: 4500 rpm at 10 gpm

MANUFACTURER: Stanley

SIZE: 14" long x 9" diameter

MODEL: GR24

WEIGHT: 11 lb in air

INPUT: 6-10 gpm
800-2000 psi

ACCESSORIES: 3/16" hex key on T-handle. Open end wrench 1 1/4" x 15" x 1/4" (modified). Socket head cap screw 1/4-28, with wide shoulder (15/16" washer welded to screw to form shoulder).

(Text Continued on Page 15)

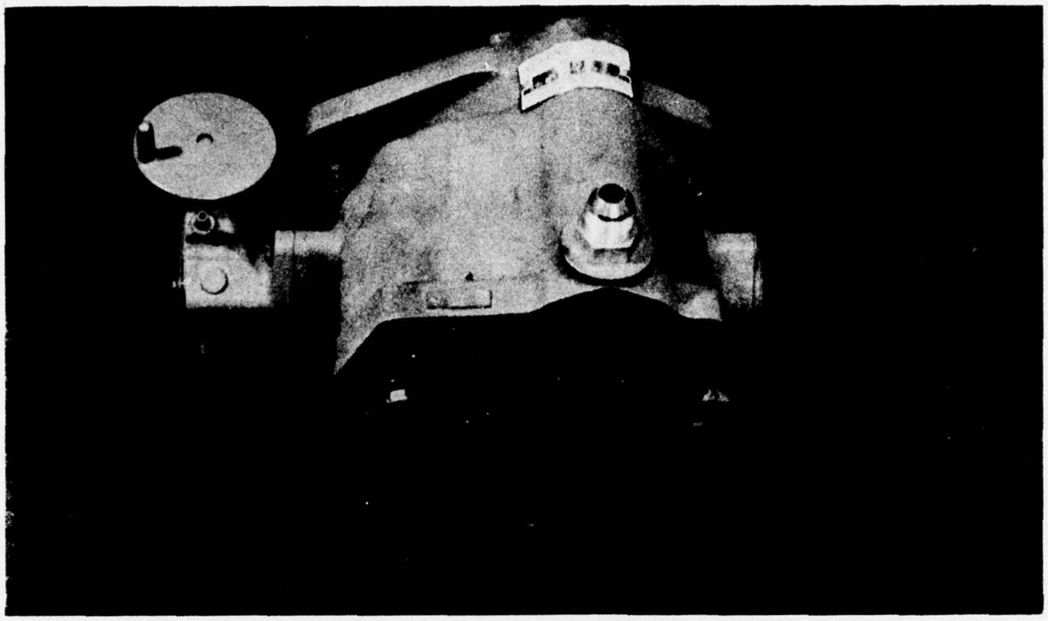

FIGURE 3-2. VICKERS VARIABLE DISPLACEMENT PUMP, DHPS

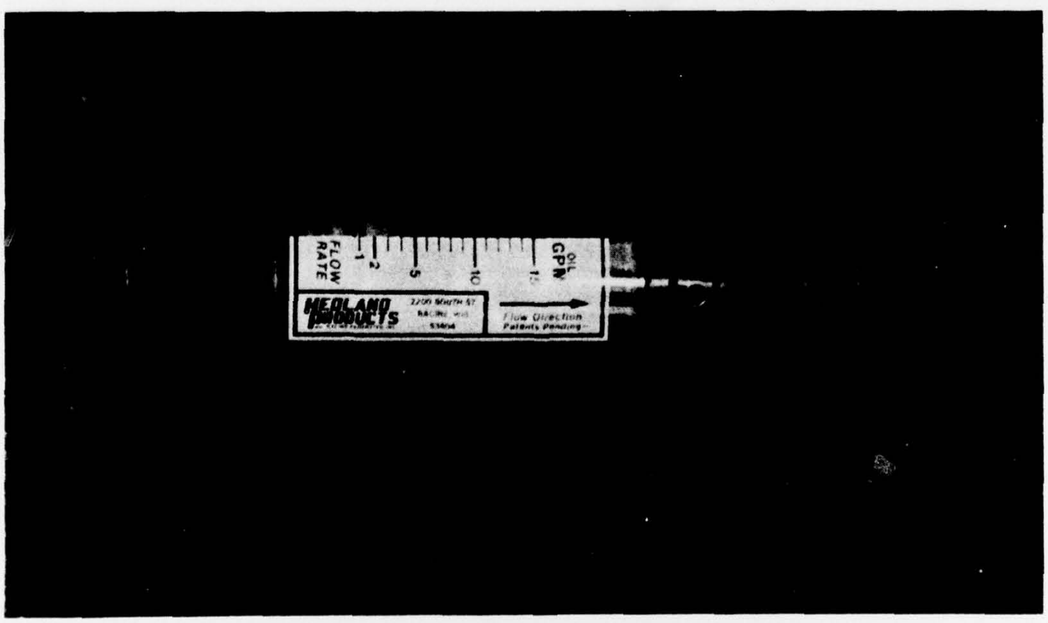

FIGURE 3-3. HYDRAULIC FLOW METER, DHPS

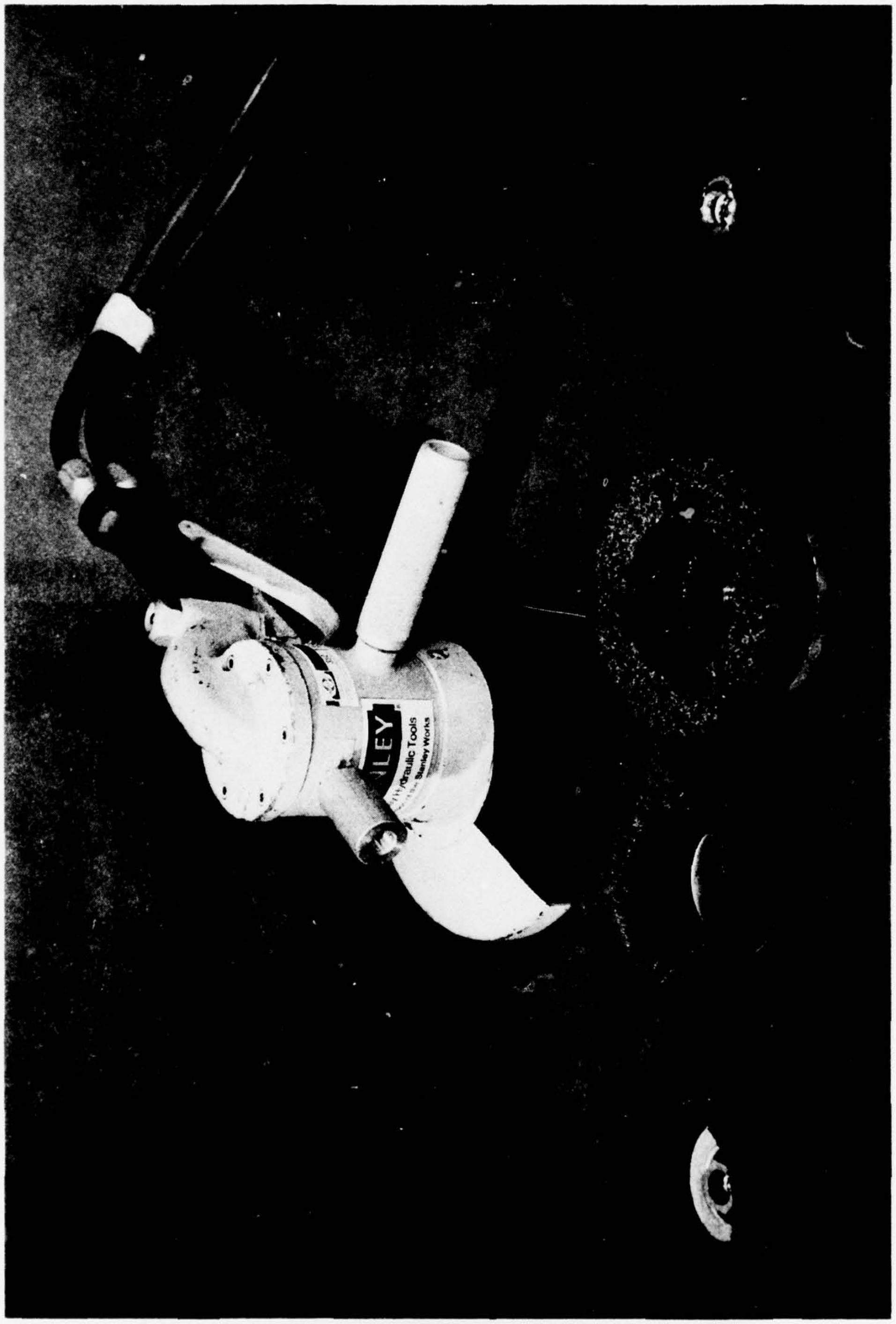

FIGURE 3-4. HYDRAULIC GRINDER, MODEL GR24

REMARKS: NOTE: Grinding wheel composition should have soft grit or soft bond for underwater use. Various brushes and wire cups can be used with this grinder.

USAGE: Cup type wheels: removing masses of metal, beveling edges, grinding weld beads. Disc type: removing nut heads or bolts, cutting through wire rope or chain links, removing welded zincs, and welded rope guards.

CAUTION: Grinder should never be operated topside without guard and eye protection. Grinding wheels used underwater should not subsequently be used topside due to danger of fragmentation.

CUT-OFF SAW: An assembly is available (NCSL) to convert the grinder to an abrasive wheel cut-off saw.

TOOL: Impact Wrench with 3/4" Square Drive

OUTPUT: 2 impacts/revolution
1050 rpm at 3 gpm (No load)

MANUFACTURER: Stanley

SIZE: 17" long x 6" diameter

MODEL: IW 13

WEIGHT: 13 lb in air

INPUT: 4-4.5 gpm
2000 psi max.

ACCESSORIES: Socket Set, 3/4 to 1½" bolt capacity.

No recent modifications have been made to this wrench (Figure 3-5).

REMARKS: USAGE: Impacting of bolts and nuts 3/4" - 1 1/2" wrench size.

CAUTION: Exceeding recommended flow rate (gpm) will cause metal chipping in impactor. Chips will jam gears. Excessive impacting on ordinary steel will strip threads or shear bolts.

TOOL: Impact Wrench with 5/8" Quick Change Chuck

OUTPUT: 2 impacts/revolution
950 rpm at 5 gpm

MANUFACTURER: Stanley

SIZE: 17" long x 6" diameter

MODEL: IW06

WEIGHT: 10.5 lb in air

INPUT: 4-5 gpm
500-1500 psi

(Text Continued on Page 16)

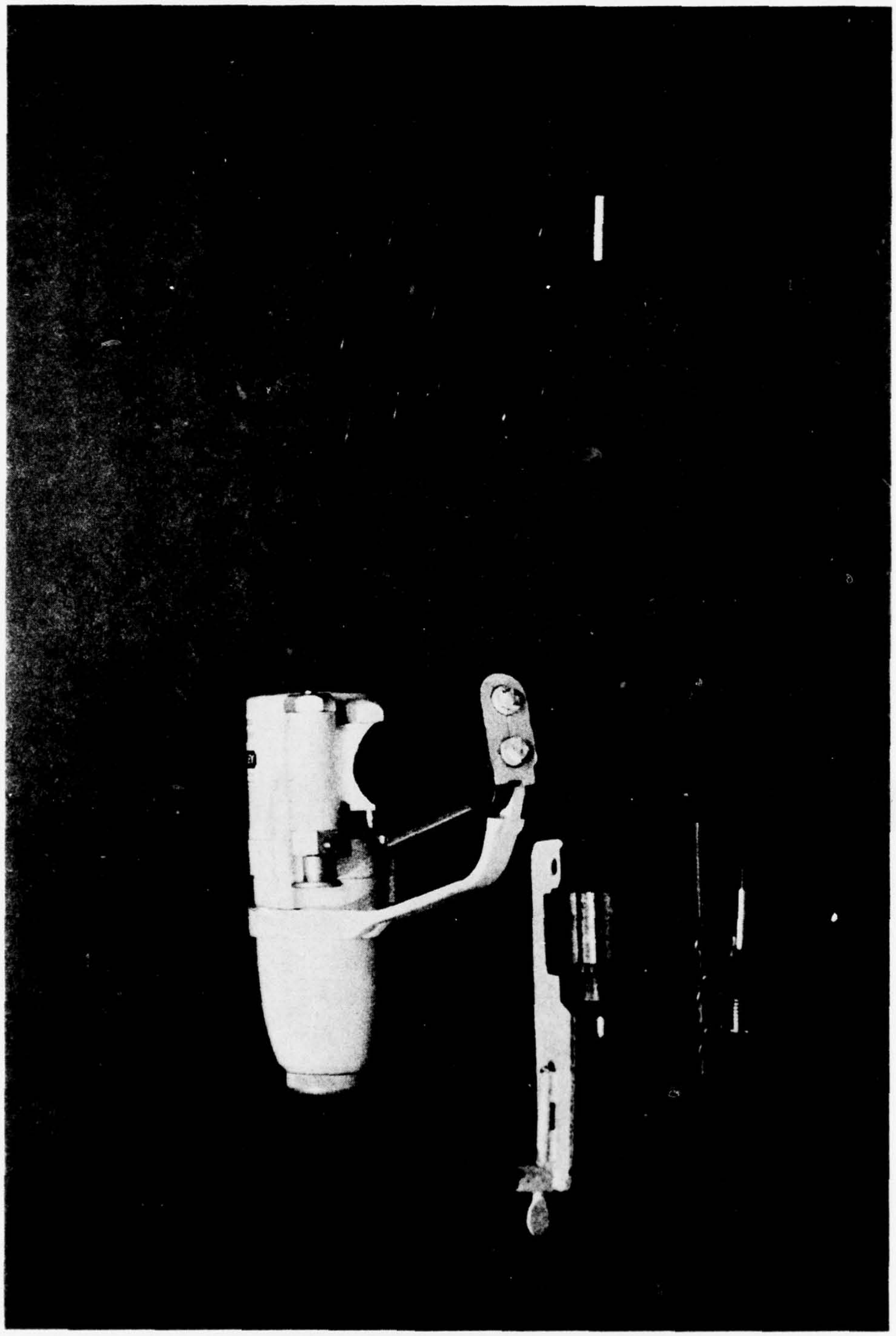

FIGURE 3-5. HYDRAULIC IMPACT WRENCH, MODEL IW13

ACCESSORIES: Jacobs Chuck 1/8" - 5/8" capacity #3 chuck key.

No recent modifications have been made to this wrench (Figure 3-6).

REMARKS: NOTE: Jacobs chuck #3B recommended for durability. Chuck modified by addition of 5/8" hex quick change shank and zerk grease fitting. Chuck key modified by addition of handle. A chuck rotation stop adapter is being developed at NCSL.

USAGE: Drill holes up to 1" diameter. Tap holes up to 1/2" diameter (mild steel or softer). Impacting of bolts and nuts 3/8" - 1" socket size. Misc. attachments include screwdrivers, allen wrenches, wood augers, etc.

CAUTION: Exceeding recommended flow rate (gpm) will cause metal chipping in impactor. Chips will jam gears. Excessive impacting on ordinary steel will strip threads or shear bolts.

Miscellaneous Tools (Nomenclature, Manufacturer and Model)

Figure Number			
3-7	Hydraulic abrasive wheel saw	NCSL	
3-8	Hydraulic spreading/pinching/cutting tool (Hurst Tool), 6-ton capacity	Hurst Performance	
3-9	Come-a-long, complete with wire rope and load hook (1 to 2 ton capacity)	Griphoist	TU 28H (2 ton) TU 17H (1 ton)
3-10	Sump/Jetting Pump	Stanley	2250H-OC
3-11	Flow divider, variable, enables the use of 2 different tools simultaneously. Includes built in flow meter.	Fluid Controls Inc./NCSL	–
3-12	Diver-operated pump, modified, output pressure to 6000 psi.	Enerpac/ NCSL	P 80 (modified)

(Text Continued on Page 24)

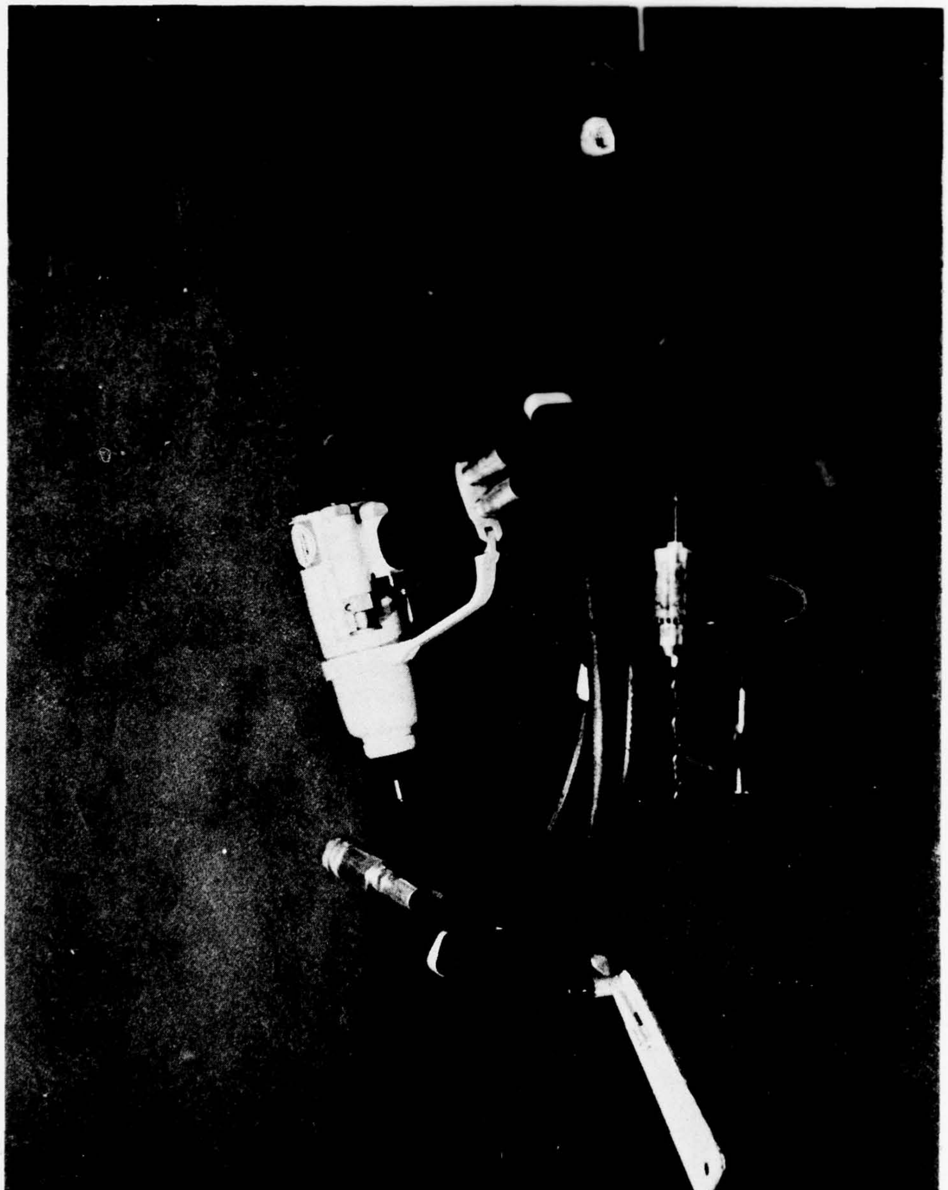

FIGURE 3-6. HYDRAULIC IMPACT WRENCH, MODEL IW06

FIGURE 3-7. HYDRAULIC ABRASIVE WHEEL SAW (NCSL)

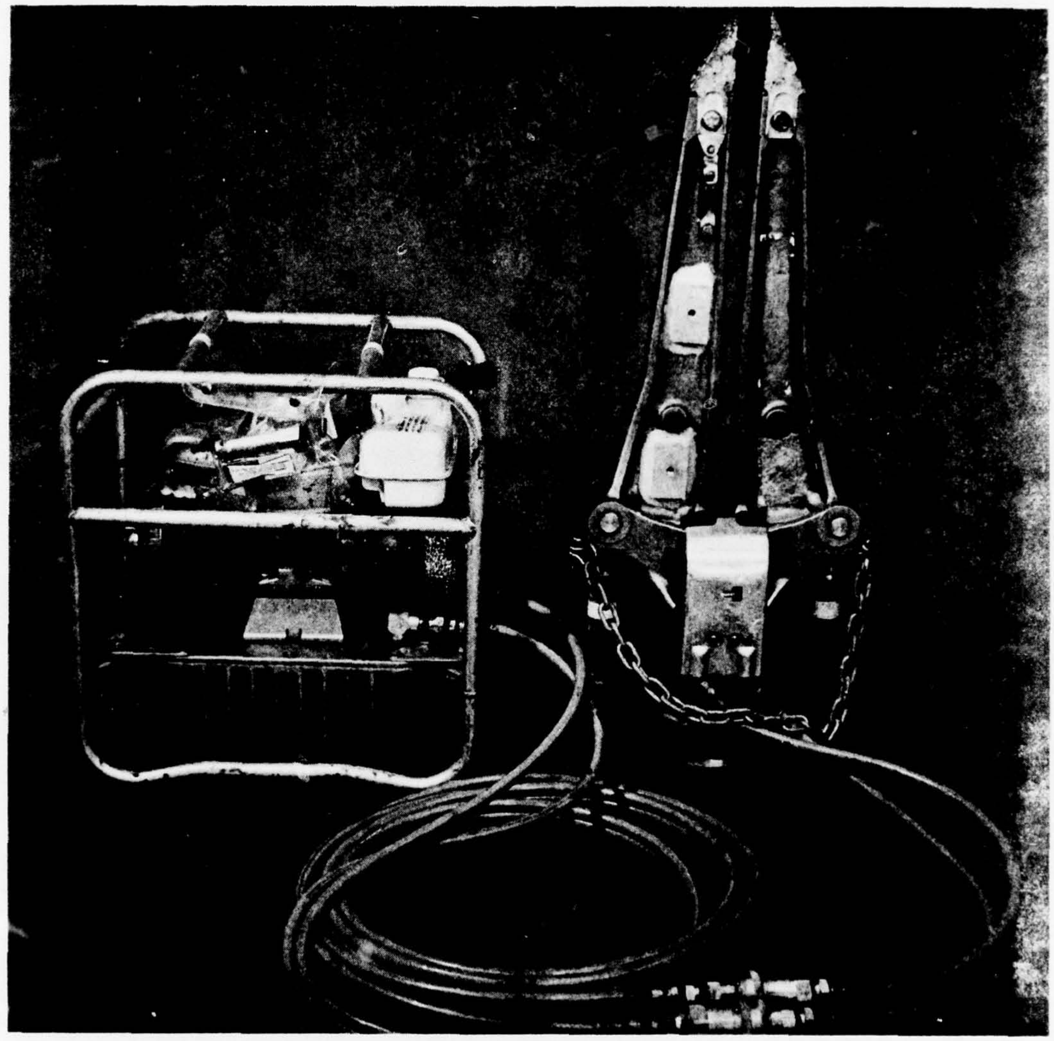

FIGURE 3-8. HURST RESCUE TOOL, HURST PERFORMANCE

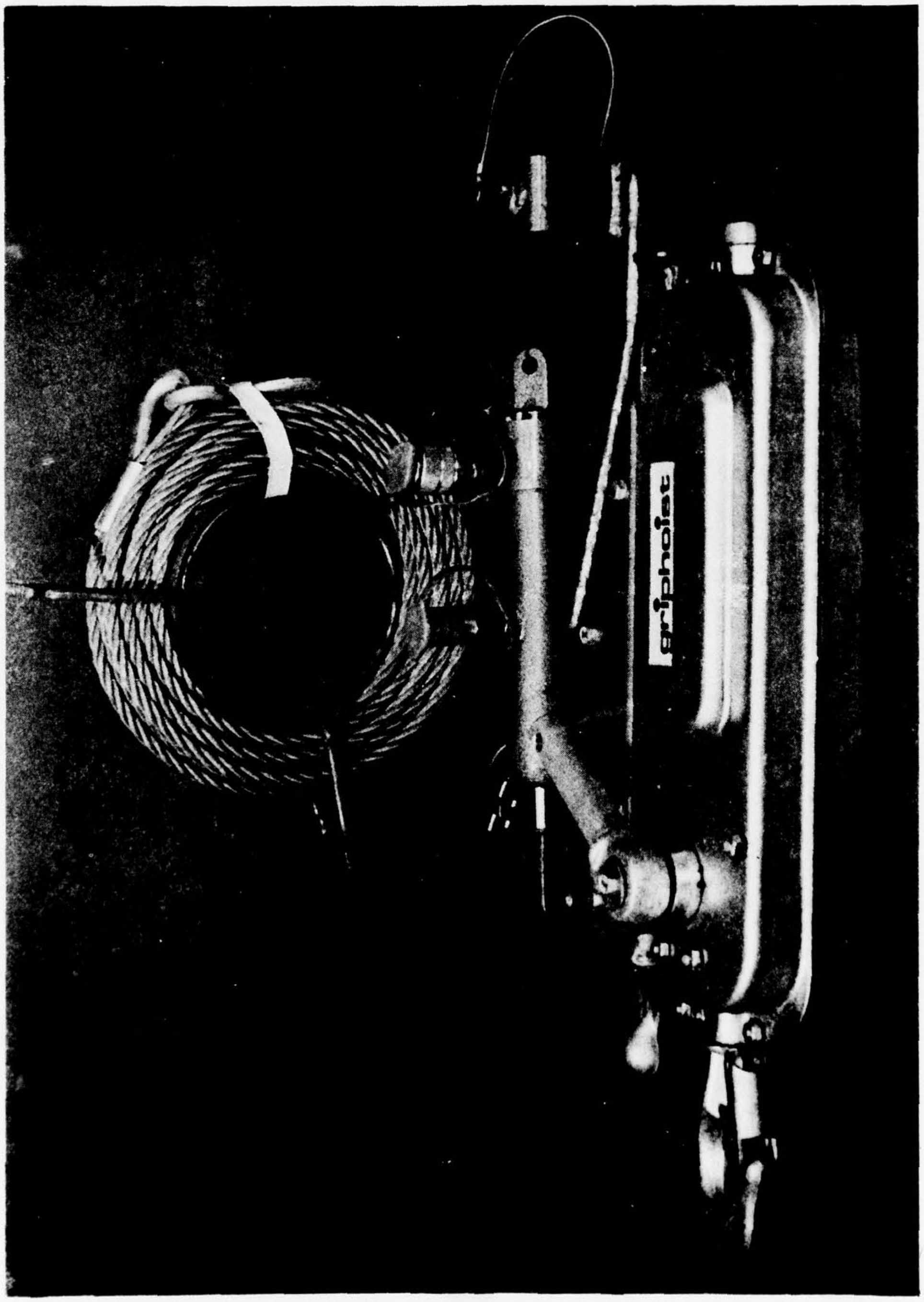

FIGURE 3-9. HYDRAULIC COME-A-LONG, GRIPHOIST

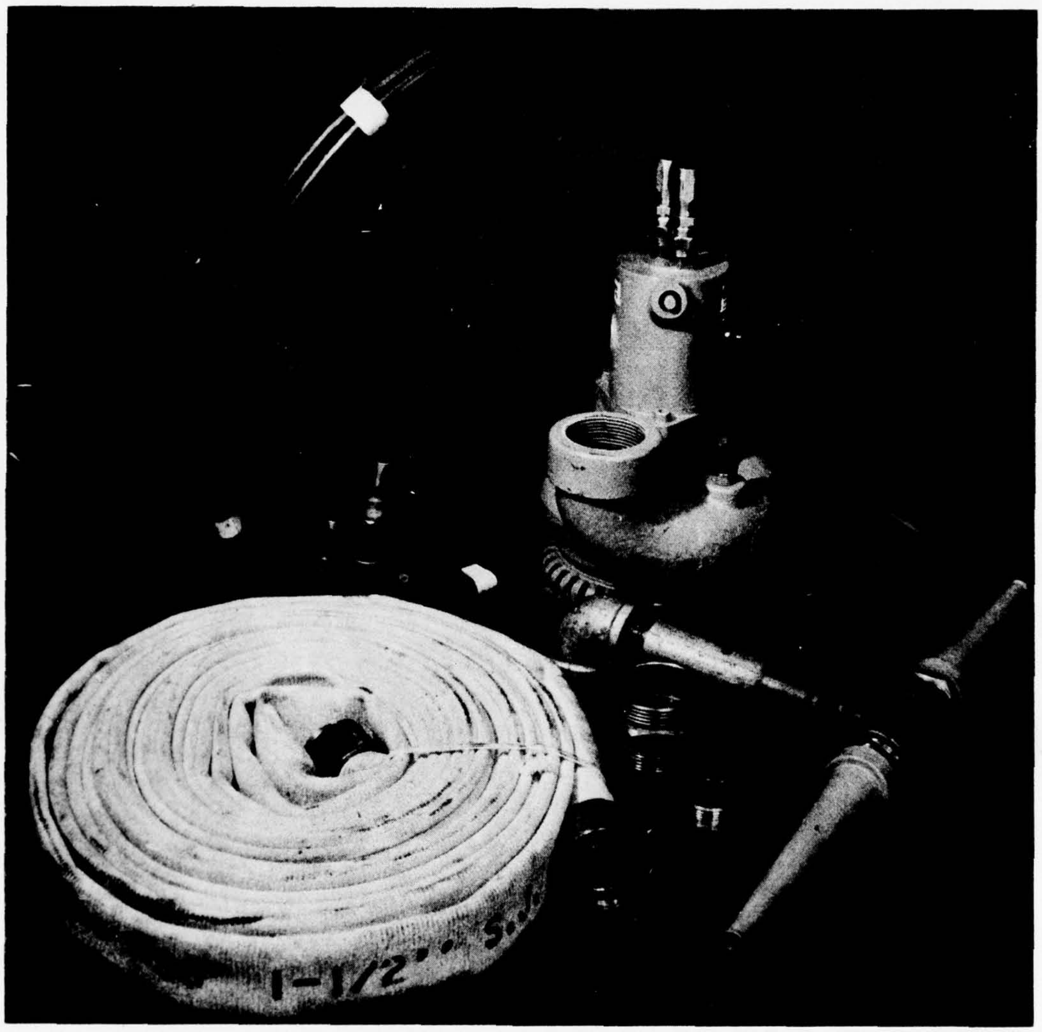

FIGURE 3-10. HYDRAULIC SUMP/JETTING PUMP, STANLEY

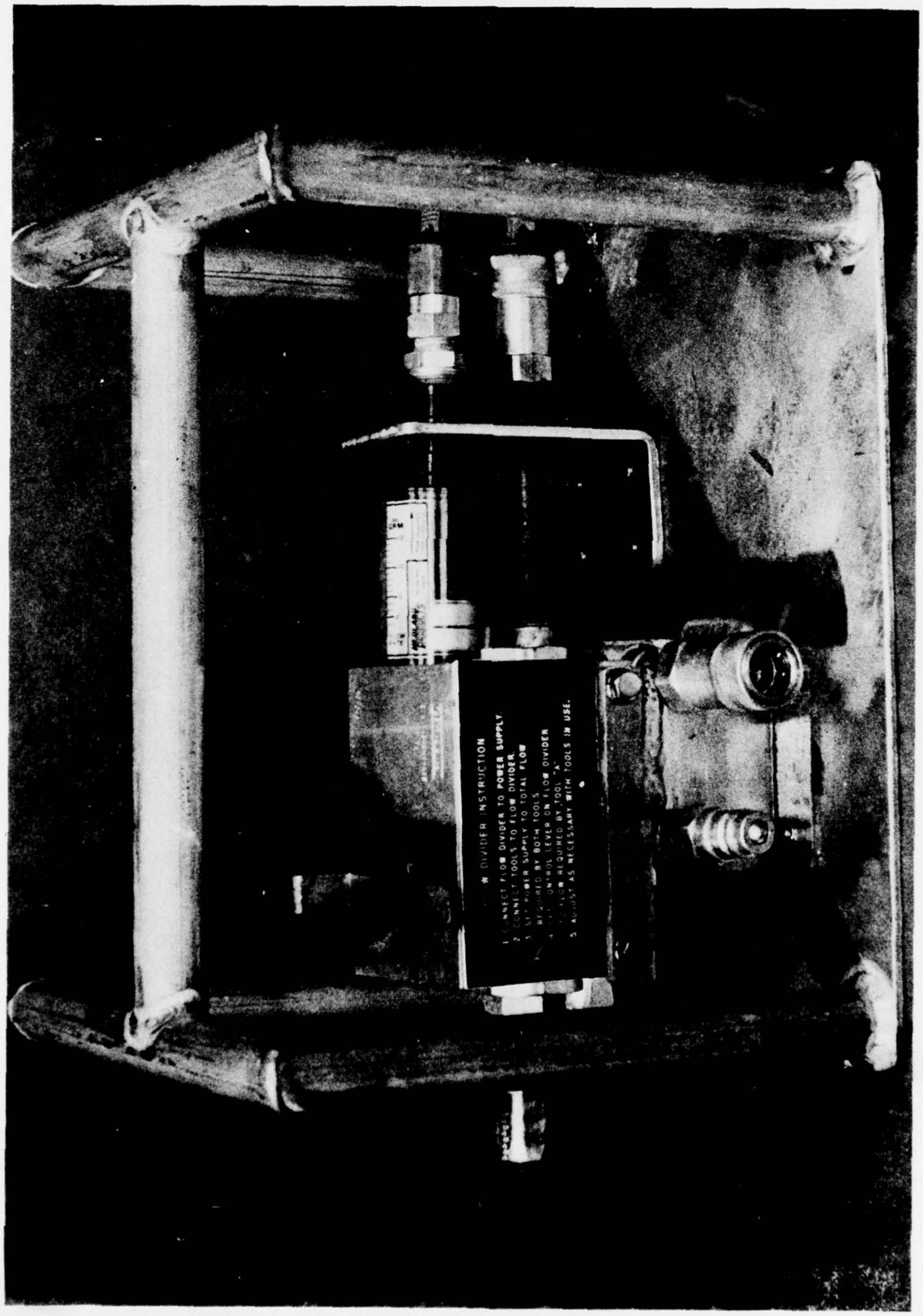

FIGURE 3-11. HYDRAULIC FLOW DIVIDER, FLUID CONTROLS/NCSL

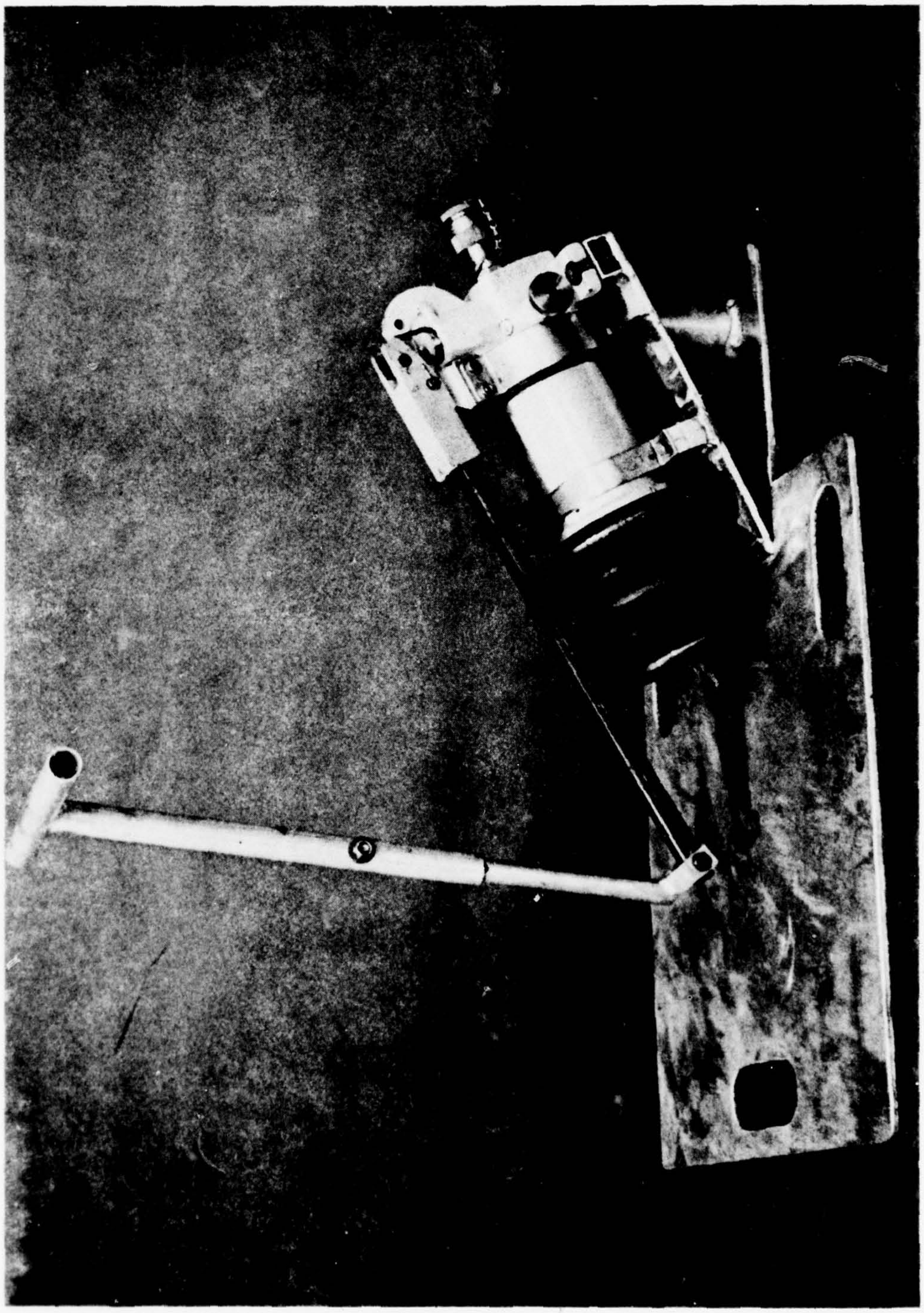

FIGURE 3-12. DIVER OPERATED PUMP, ENERPAC/NCSL

Figure Number			
3-13	Barstock cutter for rebar to 5/8" diam; ACSR cable to 1/2").*	H. K. Porter	36274
3-14	Single-acting Jack Rams (6 1/8" stroke, 10 ton	Enerpac	RC106
	(10 1/8" stroke, 10 ton		RC1010
3-15	Wire rope cutter (up to 1 1/8" diam. capacity), with spare blade (No. 21768).*	H. K. Porter	36262
	Self-contained Jack*	H. K. Porter	No. 36292
3-16	Hydraulic Pull Cylinder, 20" long, 10" stroke, 6500 lb load, with one Grab Hook, one Clevis Hook and 10' of 1/2" alloy steel chain (working load 11,000 lb), with return accumulator.	Misc. Suppliers	
3-17	Intensifier, hydraulic provides 10,000 psi, 20 cubic inch per min flow from standard power unit to operate "diver-powered" tools above.	NCSL	

MISCELLANEOUS TOOLS

3-18 Lift Bag (SUPDIV) 750 lb
Urethane impregnated nylon with pressure sealing zipper, adjustable constant buoyancy, 750 lb maximum lift capability. Complete with inflation valves and piping. Designed for use with single or double scuba bottles, (not furnished).

*Special coating applied.

(Text Continued on Page 31)

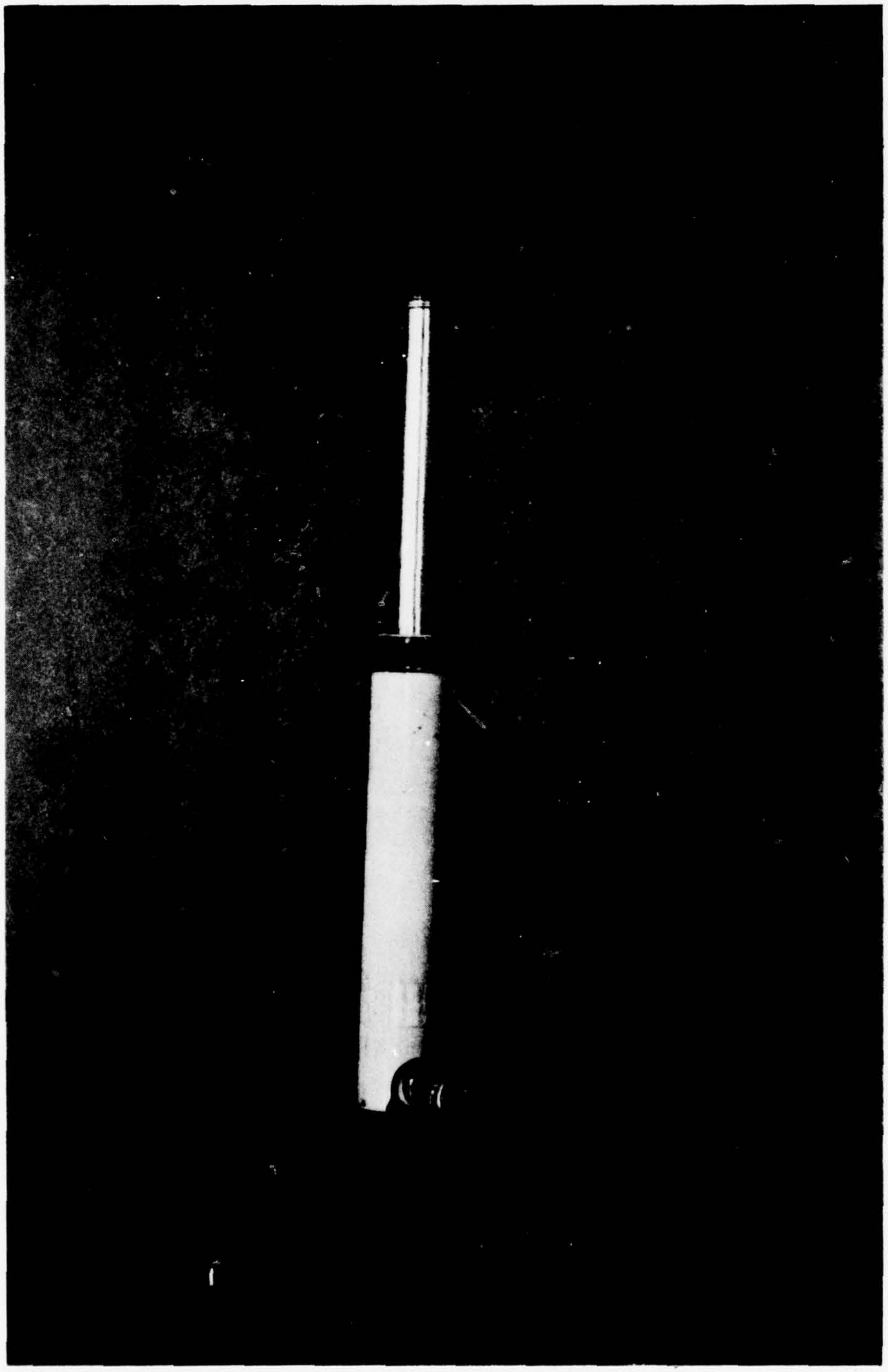

FIGURE 3-13. BARSTOCK CUTTER, H. K. PORTER

FIGURE 3-14. SINGLE ACTING JACK RAM, ENERPAC

FIGURE 3-15. WIRE ROPE, CUTTER, H. K. PORTER

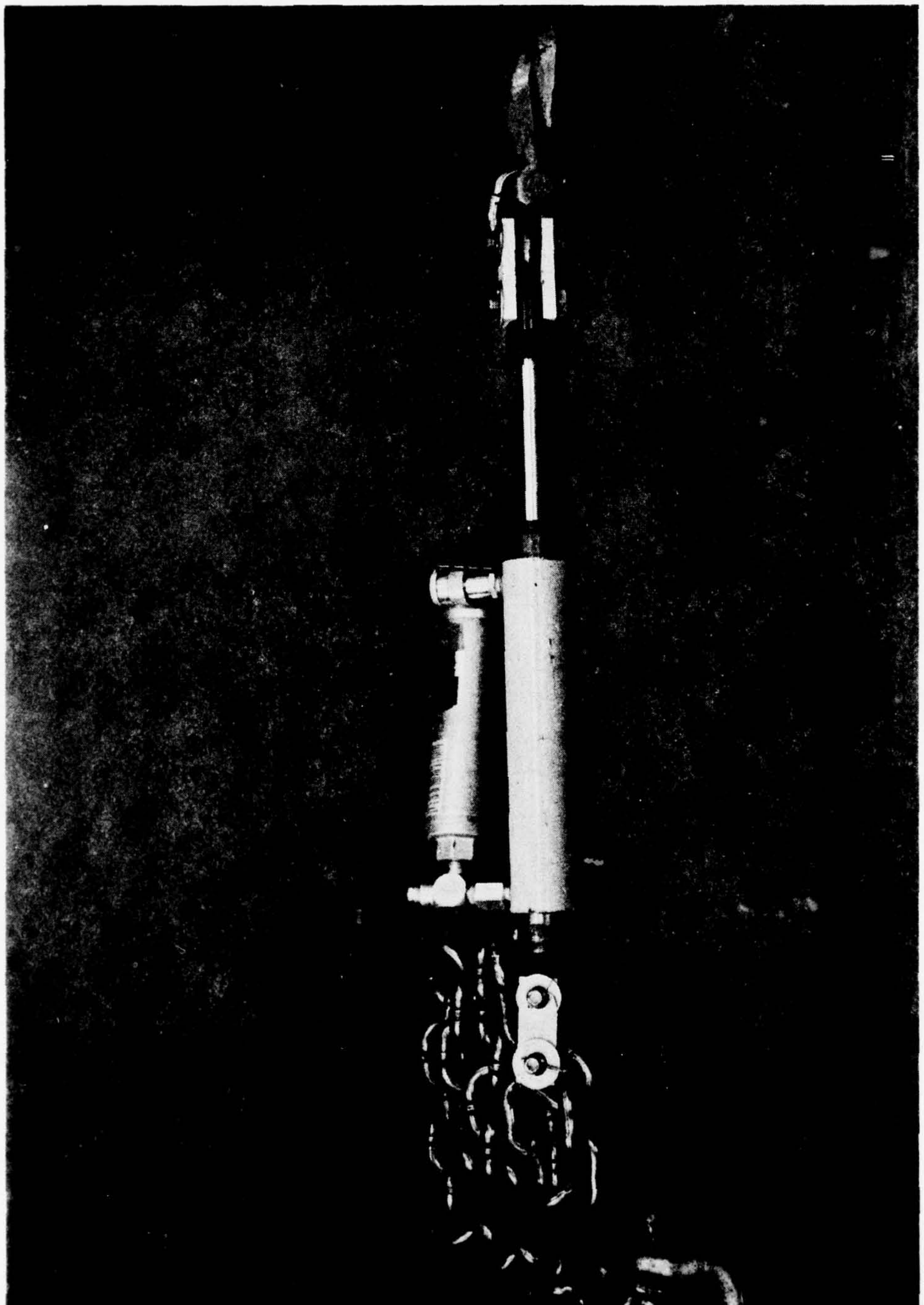

FIGURE 3-16. HYDRAULIC PULL CYLINDER, MISCELLANEOUS SUPPLIERS

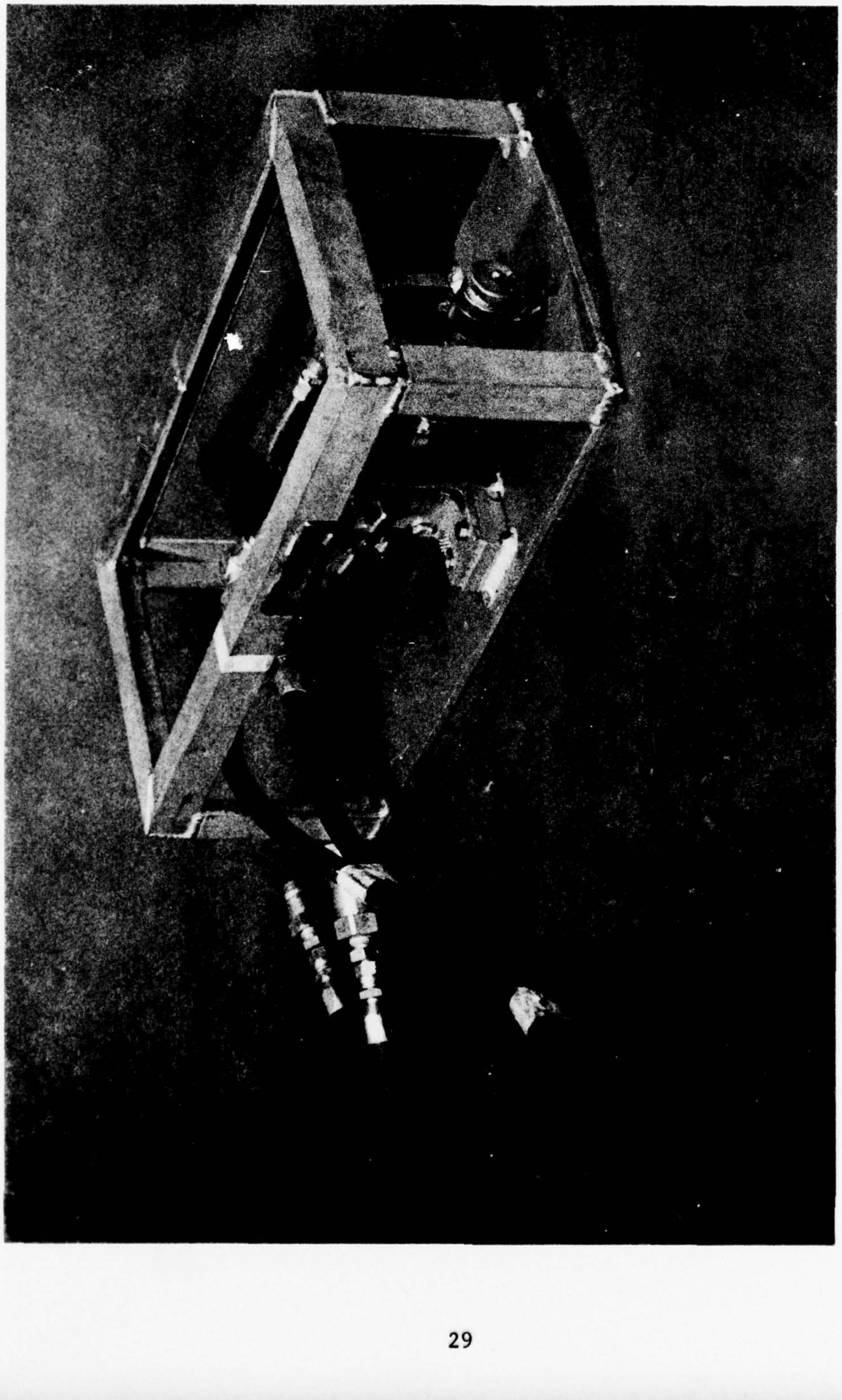

FIGURE 3-17. HYDRAULIC INTENSIFIER, NCSL

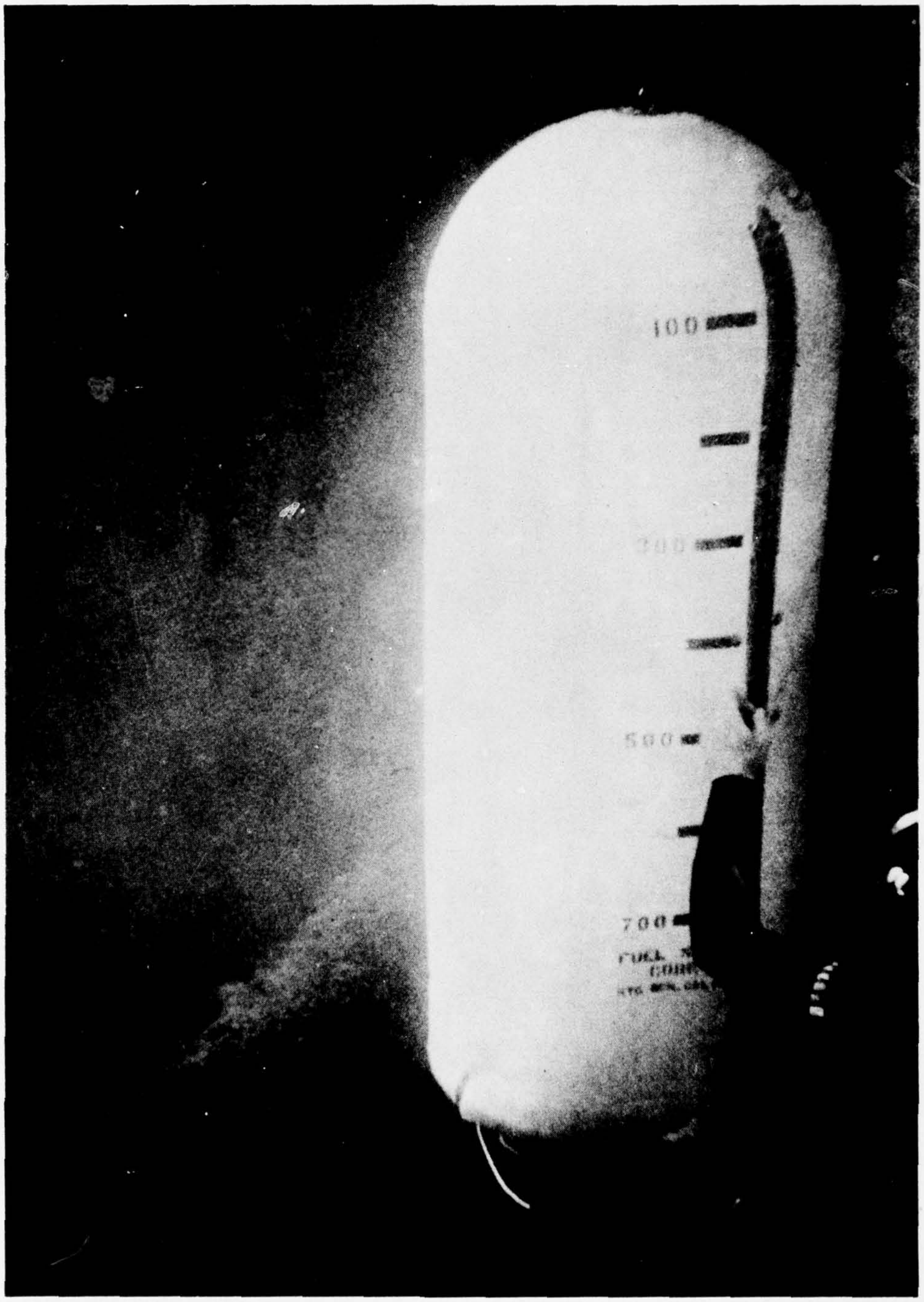

FIGURE 3-18. LIFT BAG, (SUPDIV) 750 POUND

Figure Number	
3-19	Portable Power Unit (NCSL) Self-contained, 2 modules hydraulically connectable, HATZ air-cooled diesel engine (10 hp at 3000 rpm), Vickers VIO pump (7 gpm at 3000 rpm, maximum of 1500 psi), 8½ gallon reservoir, variable relief valve and flow meter. Engine module weight approximately 294 lb. Hydraulic module weight approximately 188 lb.
3-20	Rock Drill Kit (Pneumatic Tool Sales/NCSL) 8 lb pneumatic rock drill can be used from scuba bottles (i.e., no surface support) for up to 1 1/8" diameter holes. Requires complete breakdown maintenance after use. Includes 1/2", 3/4", 1 1/8" drills, regulators, hose, and exhaust plumbing.

SECTION 4

DIVER TOOL EVALUATIONS

4.1 Informal Tests

Tests were conducted at the Civil Engineering Laboratory, Port Hueneme, California, 1967-1970.

4.1.1 Diesel Hydraulic Power Source

A commercial model hydraulic power source driven by a 20 hp, air cooled, two cylinder diesel engine was used for early hydraulic tool tests. The fluid power (7-1/2 gpm at 2000 psi) was generated by a gear pump. The unit has proved to be essentially reliable and is presently in operating condition. The hydraulic pump eventually failed and was replaced by a larger capacity (10 gpm) gear pump. The major short-comings were:

1. No pressure control (this is required due to using tools with different operating characteristics).

2. No flow control except for varying the engine speed (required for the above reason).

3. No flow meter.

Design criteria were prepared for power sources supplying power for underwater hydraulic tools (Reference 7); the appraisal presented

(Text Continued on Page 34)

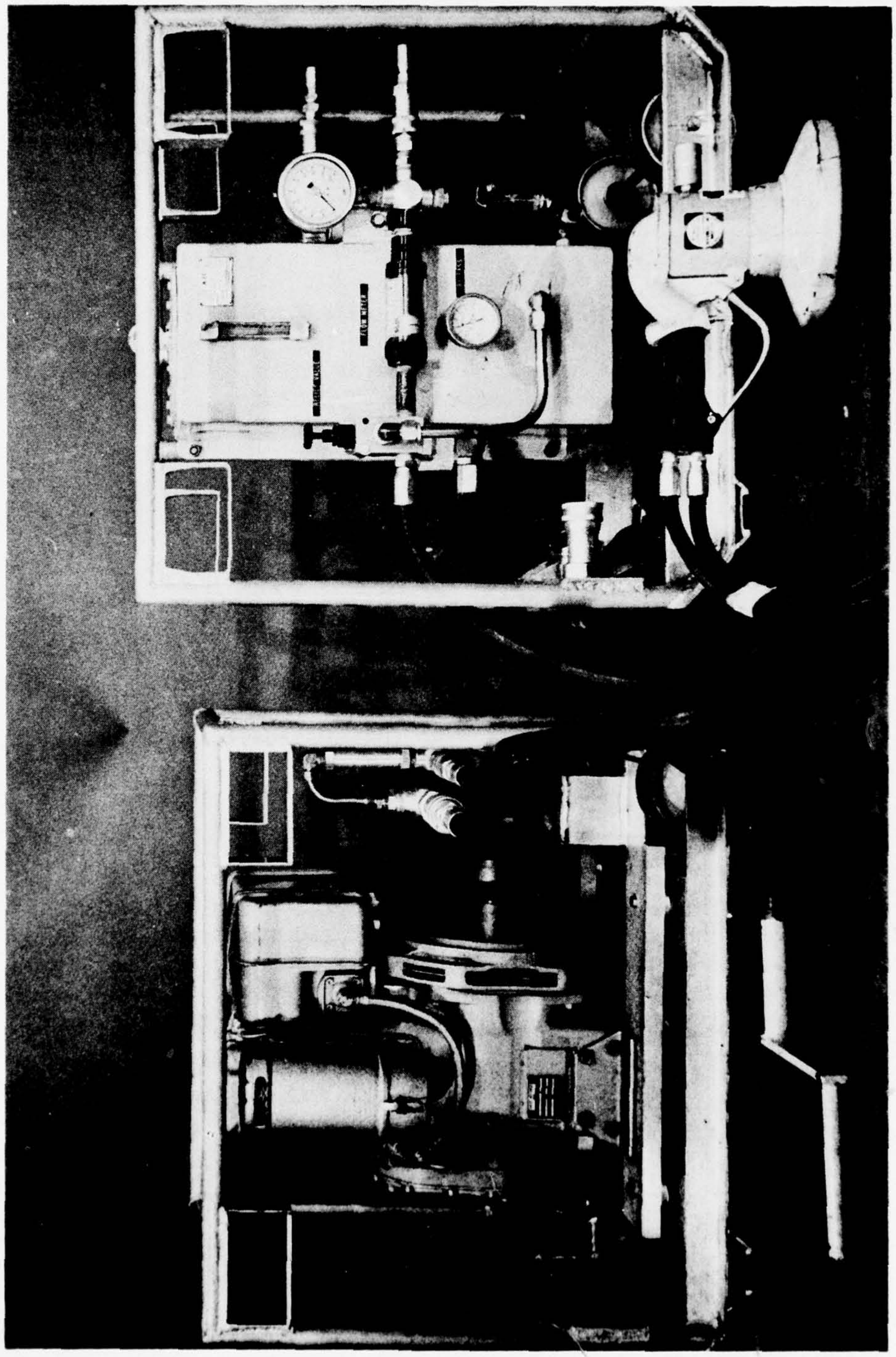

FIGURE 3-19. HYDRAULIC PORTABLE POWER UNIT (NCSL)

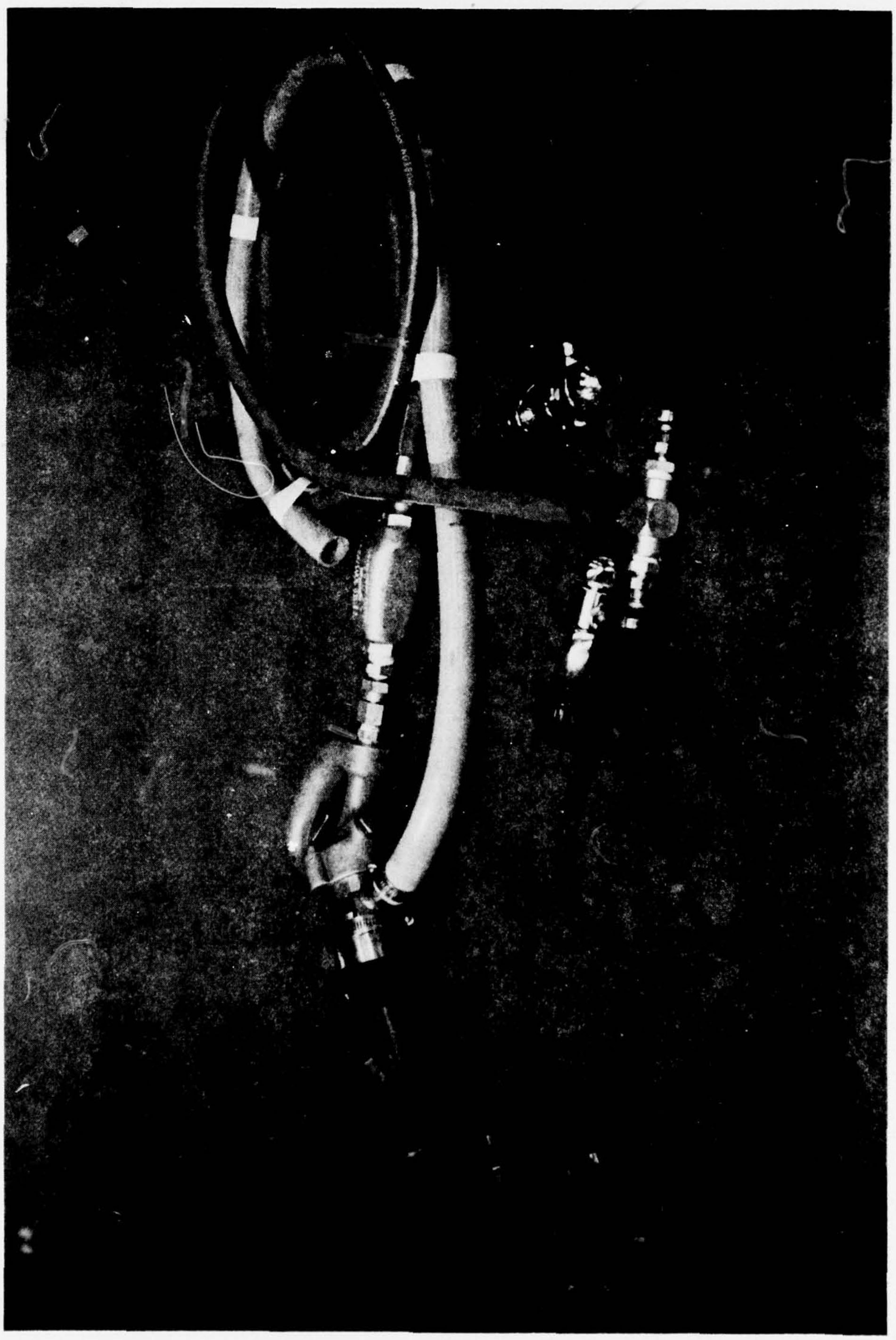

FIGURE 3-20. ROCK DRILL KIT, PNEUMATIC

the relative merits of different hydraulic circuits and components based on experience gained during NCEL's power source evaluation program.

NCEL fabricated a diesel-driven hydraulic power source following considerable experience with the commercial model previously described. The unit was made more versatile and consequently more suitable for Navy diving operations incorporating three basic changes:

1. Variable flow control (0-15 gpm).

2. Output pressure variable from 200-2000 psi.

3. Pressure, temperature, and flow gauges on a single, easily read panel. This allowed the use of hydraulic tools with widely varying pressure and flow requirements.

The NCEL diesel hydraulic power supply unit was adequate for the original use made of it such as in the tool testing programs. Field use resulted in several deficiencies explained in this report under the heading of "Informal Tests Conducted by NCSL, Panama City, Florida."

4.1.2 Hydraulic Tools

Diver tool evaluation studies began with analysis of diver performance using hand tools and hand-held pneumatic tools (Reference 1). The power tools were two drill motors, a power saw, an impact wrench, and a chipper. Initial tests were conducted on land and in a shallow waterfilled test tank. Ocean tests using the same tools were conducted at a depth of 50 feet. The performance times of the tasks were documented, and tool and accessory adequacy evaluated.

The impact wrench was the only power tool considered effective for prolonged use by divers. Some of the negative findings were:

1. The chipper created so much noise it was actually painful to the divers' ears.

2. Air exhaust from the tools partly obscured the divers view.

3. Maintenance of the pneumatic tools required an excessive amount of time, which, even then, did not result in satisfactory tool reliability.

4. Pneumatic tools are depth limited due to air supply problems.

The tool evaluation program was soon expanded to include both pneumatic and hydraulic tools and power supplies. The tools included a pneumatic and a hydraulic impact wrench and a hydraulic chain saw and grinder. The Ackley Grinder used was essentially the same tool as

provided in the Navy diver tool kits. The commercial diesel driven hydraulic power supply described earlier in this section was used.

A special tool array was fabricated to permit overhead, vertical, and deck diver work positions. Testing was done at shallow depths in the harbor at Port Hueneme, California. There is a high correlation between diver-tool performance in shallow water and at deeper ocean depths (as long as tool depth limits are not exceeded), but the costs were substantially less.

The basic conclusions and recommendations for tools and accessories are listed in Table 4-1 and are discussed here.

1. The hydraulic tools were very effective and practical at test depths and should be equally effective at much greater depths. Pneumatic tools lose efficiency as the depth increases and are not recommended for depths below 120 feet.

2. Diver skill in effective tool use is very important and a knowledge of safe handling procedures is mandatory. Selection and training of divers in the use of tools underwater is necessary for optimum safety and work effectiveness.

3. All of the power tools, and in particular the chain saw, are potentially dangerous. Thorough procedures must be established for safe tool use, general diving safety, and rescue techniques.

4. The use of scuba gear provides the working diver with greater freedom for positioning tools on the work surfaces. With surface-supported diving systems the diver must take added precautions to ensure that his life line and air hose do not become entangled with the tool umbilicals or are damaged by the tool.

The next series of reported tests at NCEL were expanded to include hydraulic tools which could be powered by the diver using a modified hydraulic pump. Included were a hydraulic ram which could be used as a jack or a pull cylinder, and wire rope and bar stock cutters. These are early revisions of similar tools found in the Navy hydraulic tool kit. The NCEL diesel driven hydraulic power supply was used in conjunction with a hydraulic winch and power hack saw.

4.1.3 <u>Summary</u>

1. The underwater tests determined the feasibility of using diver-powered hydraulic equipment for underwater salvage operations. The hydraulic equipment is commercially available and requires only nominal modifications and simple maintenance for reliable underwater

(Text Continued on Page 37)

TABLE 4-1

CONCLUSIONS AND RECOMMENDATIONS FOR TOOLS AND ACCESSORIES

Item	Conclusions	Recommendations
Pneumatic impact wrench	Depth limited and requires excessive maintenance, but light and relatively easy to handle.	Design for ease in assembly and disassembly to facilitate maintenance.
Hydraulic impact wrench	Very effective for drilling, tapping, and bolt and nut impacting; controls should be improved.	Move Forward—Reverse control to the rear of the motor where it is more accessible. Conduct tests to determine if On-Off control can be released rapidly in an emergency; if not, modify. Conduct tests to determine optimum rotary speed for drilling, using realistic diver-applied forces.
Hydraulic chain saw	Effective for light use, but lacks adequate power for heavy work; some modifications are required.	Modify handle and add adjustable dog. This will permit the operator to exert force directly in line with the saw chain and to gain more leverage in cutting.
Hydraulic grinder	Very effective for underwater use, but difficult to handle; both hands are required for operations; tethering and/or staging required.	Modify On-Off control. Conduct tests to determine optimum grinding wheel materials, peripheral speeds, and configurations.
Hoses and connectors	Pneumatic hoses adequate, but hydraulic hoses stiff and lack proper swivel mechanisms at the motor connection.	Tests should be conducted to determine if lighter, more flexible hoses can be used. The feasibility of using concentric hoses with the supply hose located inside the return hose and a single swivel connector should be investigated. The swivel should be designed to permit rotation in two planes.
Tool accessories	Both the keyless and key-type chucks were time-consuming to use and jammed when using the impact mode. Tool-holding devices were not entirely satisfactory as it was difficult to locate the tool accessories, especially in murky water.	All tool bits should be provided with adapters that would permit direct mating to impact motor for maximum diver efficiency. Special tool-holding devices should be fabricated to permit prearrangement of all tool bits by size. All items should be visible and accessible to the diver.

operation. However, it cannot be overemphasized that utilizing the diver as the power supply is justifiable only for small tasks and in emergency situations. For repetitive underwater work tasks the diver must be used as a tool operator and not as a power supply. Using the diver as the power supply on a large task may tire him so that his safety is jeopardized.

2. A modified two-stage hydraulic pump was used to convert the diver's energy to hydraulic power. With this type of pump, a diver can be expected to generate fluid power to operate small rams, hydraulic cylinders, and cutters. The hydraulic rams and cylinders are limited to approximately a 2-inch internal diameter with a 10- to 12-inch stroke to keep the pumping cycle less than 5 minutes and to permit easy diver handling of the components.

The diver-powered hydraulic pumps can be used to supply up to 5 cubic inches per minute of 4000 psig hydraulic fluid for periods up to 20 minutes. The diver-powered pump systems are relatively inexpensive, do not require surface support, and can be moved underwater by the divers.

3. The hydraulic-actuated cutting equipment suitable for underwater operation is available for cutting wire rope to 1 1/2 inch diameter and for steel bars to about 3/4 inch diameter. Additional open center cutting tools are required. Presently a cable cutter is available but needs improvement to perform satisfactorily. There is no diver operated hydraulic equipment commercially available for cutting flat steel plate.

4. Of the three open center hydraulic salvage tools evaluated—a cutter, a power handle driven winch, and a hacksaw, none are recommended for Navy use in their present form. The cutter promises to be a very useful tool when the cutting mechanism is improved. It also would be advantageous to reduce the tool weight. The "disposable" winch and power handle concept appears to be promising for extensive underwater salvage operations. The hydraulic hacksaw is not a satisfactory diver tool in its present form.

4.2 Additional Informal Tests.

Additional tests were conducted or monitored by Naval Coastal Systems Laboratory, Panama City, Florida (1973-1975).

4.2.1 Diesel NCEL Hydraulic Power Source

Use of the diesel-driven power source in warm climates such as Panama City, Hawaii, and Subic Bay resulted in overheating of the hydraulic fluid. When the power source was used for individual tools that

required less than the maximum flow rate, the unused portion of the total flow would circulate through a relief valve and back to the reservoir. This resulted in increased friction and related heat problems. In colder climates the submerged hose would radiate more of the heat into the sea. To correct this problem, the original constant flow pump has been replaced with a Vickers variable displacement piston pump. Now the flow can be adjusted to meet the requirements of individual tools.

The original flow meter lacked accuracy at low flow rates. A Headlands Products flow meter has been substituted which is more accurate and easier to read.

Occasionally the diesel oil fuel tank requires cleaning due to contamination. The tank was very difficult to remove because it was located below several items of equipment that had to be removed first. The unit has been modified so that the tanks can be removed from the bottom.

Simplification of the hydraulic lines and fittings have also been made.

Planned modifications include a fuel tank dip stick and an access plate for cleaning of the fuel tank.

4.2.2 Hydraulic Tools

The hydraulic grinding and impact wrenches have been found to be adequate and have not been modified.

The basic hydraulic motor used for the grinder has been used for a scrub brush and a recently developed abrasive wheel saw, with a "skill saw" like configuration. Both of these tools are effective for underwater work.

Table 4-2 lists some of the problems identified by Fleet users in correspondence with NCSL.

4.3 Diver Tools Used in Mark 12 Technical Evaluation (1973)

The purpose of the technical evaluation was to determine the operational effectiveness and the technical suitability for service use of the Surface Supported Diving System USN Mk 12. The tests combined operational testing with human engineering and human factors testing to depths of 300 feet under four separate environmental conditions: open tank, hyperbaric chamber, Anocostia River, and open sea. Diver power tools were used to provide realistic diver oriented work for all phases of the testing. The general results have been reported by the Naval

(Text Continued on Page 40)

TABLE 4-2

FLEET IDENTIFIED DIVER TOOL KIT PROBLEMS

Fleet Unit	Hydraulic Power Unit	Grinder	Impact Wrenches
Naval Ship Repair Facility Subic			Gear housing cracked. Hammer and anvil battered. gear housing sea water intrusion of gear housing.
Harbor Clearance Unit I	Hydraulic oil temperature excessive.	Lacked adequate torque	Better chuck key required. Need larger drill motor.
Harbor Clearance Unit II	Unit is too large and heavy for use on 40' utility boat.		
Naval School EOD, Indian Head, MD	Lock nuts on flow regulator and relief valve bind.	Guard traps water and produces excessive torque.	Drill chucks bind.
Salvage Diving System-450			Chuck key does not fit properly and chuck binds.
OPNAV Project T/S 83			Chuck binds.

Medical Research Institute (Reference 11) and by the Experimental Diving Unit (Reference 12). The following diver tools were used during the testing program:

Stud Gun
Ackley Grinder
Ackley Impact Wrench
Abrasive Saw
Sump/Jetting Pump
Diver Power Pump
Barstock Cutter
Power Actuated Stud Driver
Lift Bag (NMRI).

Navy enlisted divers from the Experimental Diving Unit and from Harbor Clearance Unit I were used as test divers.

The general conclusions concerning the tools were:

"The tools were used by divers in the Mk V and Mk XII tests with no apparent problems. In general, diver comments favored the tools. Some difficulty was experienced in drilling and tapping with the impact wrench. Based on use of the tools during the evaluation, it appears the Fleet indoctrination of the tools should be successful and should lessen diver fatigue on extended salvage jobs."

Mr. Martin Sheehan, NCSL Equipment Specialist provided instruction in the use of the power tools, maintained the hydraulic power unit and tools, and debriefed the divers following completion of the tests by means of a questionnaire.

Portions of the questionnaire responses which are directly related to the hydraulic power unit and tools for which service approval is being sought will follow.

4.3.1 Tool Ratings

The diver ratings of tools are summarized in Table 4-3.

4.3.2 Specific Recommendations

The test divers were asked to make recommendations for improving the tools and equipment. The following code is used to identify the divers responsible for the recommendations:

(Text Continued on Page 42)

TABLE 4-3

RATING SUMMARY

Item	Number of Responses		
	Very Satisfactory	Satisfactory	Unsatisfactory
Hydraulic Power Supply			
1. Adequate pressure and flow rates	4	11	
2. Adequate controls for pressure and flow	5	10	
3. Handling	5	10	
4. Starting	5	10	
Ackley Impact Wrench			
1. Drilling and/or tapping	11	4	
2. Nut running and removal	11	4	
Ackley Grinder			
1. Grinding welds, beveling edges, etc.	8	7	
2. Used as an abrasive saw to cut wire rope, bolts, etc.	6	7	3
3. Adequacy of torque	5	9	1
4. Adequacy of grinding wheels	4	11	
Sump/Jetting Pump			
1. Utilized as a jetting tool	1	5	2
2. As a pump	1	6	1
Lift Bag (NMRI)			
1. Used by divers to lift 50-500 lb	5	8	
2. Adequacy of controls	3	7	4
3. Adequacy of rigging	2	11	
Diver Operated Pump			
1. Pump & Pump Stand	1	7	4
2. Connecting and Dis-connecting tools	3	9	1
Barstock Cutter	7	5	1
Wire Rope Cutter	4	8	1

Code	Diver	Rate	Organization
D.A.	Dick Arlington	BMC (DV)	Experimental Diving Unit
G.B.	Gerald Baker	HT1 (DV)	Experimental Diving Unit
R.B.	Ralph Bowdish	BM1 (DV)	Experimental Diving Unit
J.C.	John Cantale	EM1 (DV)	Experimental Diving Unit
T.E.	Terry Everson	BM2 (DV)	Experimental Diving Unit
B.H.	Bob Holloway	BM1 (DV)	Experimental Diving Unit
T.R.	T. Rossi	BM1 (DV)	Experimental Diving Unit
E.A.	Ernest Alexander	HTCS(DV)	Harbor Clearance Unit I
D.B.	Dale Brown	BM1 (DV)	Harbor Clearance Unit I
D.M.	Dennis McNight	EN2 (DV)	Harbor Clearance Unit I
N	Norris	MR3 (DV)	Harbor Clearance Unit I
A.R.	Alex Romero	HT1 (DV)	Harbor Clearance Unit I
M.S.	Michael Stott	CWO-3	Harbor Clearance Unit I
J.T.	J. Thompson	BMC (DV)	Harbor Clearance Unit I
B.W.	Billy Whitfield	HT1 (DV)	Harbor Clearance Unit I

The recommendations concerning the Hydraulic Power Unit are listed in Table 4-4, the Impact Wrench in Table 4-5, and the Hydraulic Grinder in Table 4-6. Also the necessity for the recommended change is rated.

TABLE 4-4

TOOL CHANGE RECOMMENDATIONS
HYDRAULIC POWER UNIT

Diver Code	Recommendation	Rating: Mandatory	Rating: Desirable
R.B.	Change from electric to hydraulic start.		X
E.A.	Mount the hydraulic supply on a cart with stowage available for all tool units, hose, and related equipment.		X

(Text Continued on Page 45)

TABLE 4-5

TOOL CHANGE RECOMMENDATIONS - HYDRAULIC IMPACT WRENCH

Diver Code	Recommendation	Rating: Mandatory	Rating: Desirable
D.A.	Relocate handle grip and trigger. Design tool for two handed operation.	X	
R.B.	Change directional rotation control from a plunger to a lever.		X
D.B.	Make a better chuck key.		X
D.M.	The direction of rotation switch was hard to push in and out; suggest you add a more accessible lever.	X	
M.S.	Provide a more adequate chuck key.		X
J.T.	Provide tension type wrench to prevent over tightening of chuck.		X
B.W.	Have instructions prepared to let the user know that hand tightening of drill bits and taps is sufficient and proves faster.	X	
B.W.	Provide the best drill bits.		X

TABLE 4-6

TOOL CHANGE RECOMMENDATIONS - HYDRAULIC GRINDER

Diver Code	Recommendation	Rating: Mandatory	Rating: Desirable
D.A.	Extend shaft a few inches to allow for wide angle of application.		X
G.B.	Improve handle.		X
R.B.	Change motor housing to a non-corrosive metal.	X	
J.C.	Increase horsepower and provide better grinding wheels.		X
T.R.	Provide a smaller hand grip.	X	
D.M.	Grinder would stall out under pressure. The switch lever would tire your hand after long periods of use.	X	

TABLE 4-7

TOOL CHANGE RECOMMENDATIONS - SUMP/JETTING PUMP

Diver Code	Recommendation	Rating Mandatory	Rating Desirable
R.B.	Add a better strainer when used as a pump.		
J.C.	Provide more power.		
T.R.	The sump pump needs a finer strainer on the suction side.	X	
D.M.	If you could build a pump with a 2 1/2" discharge that puts out the same pressure and volume as a salvage jetting pump, it would be an outstanding piece of gear.		X
B.W.	Increase the pressure.	X	

TABLE 4-8

TOOL CHANGE RECOMMENDATIONS - DIVER OPERATED PUMP

Diver Code	Recommendation	Rating Mandatory	Rating Desirable
J.C.	Provide a better secured pump and improved base. Improve the power stroke.	X	
B.H.	If you were using scuba it would be advisable to make it so you wouldn't have to use so many strokes.	X	
T.R.	The pump should be fixed to a solid object rather than the metal plate.		X
E.A.	Provide a larger wire rope cutter and better seals and valves on the pump unit.	X	
D.M.	Improve the connection between the pump handle and the piston.	X	
N	Use a shorter handle so you will have a shorter stroke.		X
A.R.	Provide a heavier base.	X	
M.S.	Provide shorter hose lead. Add a wire rope cutter of 2" capacity.	X	
	Reduce the size and increase the efficiency of the pump.		X
B.W.	Provide heavier base or mount in cage.	X	

4.4 Diver Tools in Additional Mark 12 Technical Evaluation (1976)

Modifications were made to the MK 12 system and evaluation testing continued in 1976. Diver tools were used primarily to add realism to the tasks used as diver performance measures of the adequacy of the MK 12 system. Navy enlisted divers from the Experimental Diving Unit served as test divers.

A Stanley hydraulic impact wrench and grinder, and Enerpac diver operated pump with a H.K. Porter barstock cutter and wire rope cutter were included in the diver tools.

Tool operation and safety are evaluated below.

	Operation				Safety			
Tool	Very Well	Satis.	Poor	Unsatis.	Very Safe	Safe	Marginal	Unsafe
Impact Wrench	9	2			6	5		
Grinder	6	4			2	6	1	
Pump, barstock cutter and wire rope cutter	5	1			6	2		

Diver identified problems and related recommendations are listed in Table 4-9.

4.5 Hydraulic Tool and Power Supply Questionnaire

The questionnaire was prepared to obtain data required for service approval and to serve as a basis for planning tool modifications or additions. The questionnaire was mailed to 14 Navy units that had received the Navy hydraulic tool kit. Completed questionnaires were returned by the following:

Summary Code	Navy unit	Location
CEL	Civil Engineering Laboratory	Port Heuneme, CA.
HCU-I	Harbor Clearance Unit I	Pearl Harbor, Hawaii
NSDS	Naval School, Diving and Salvage	Washington, D. C.
NSCDS	Naval Second Class Diving School	San Diego, CA.
NSRF	Naval Ship Repair Facility	Subic Bay, Philippines
NSSF	Naval Submarine Support Facility	New London, Conn.
UCTI	Underwater Construction Team I	
SDGI	Submarine Development Group I	

The abbreviations under the heading "summary code" are used to identify the unit making the input.

(Text Continued on Page 47)

TABLE 4-9

DIVER IDENTIFIED PROBLEMS AND RECOMMENDATIONS

Tool	Problems	Recommendations
Impact Wrench	Some difficulty in loosening chuck. Chuck tightens too much under impacting. Difficulty in getting the pilot drill out.	None.
Grinder	When the grinding disc shattered the arbor continued to rotate even after releasing the trigger.	Provide a more positive ON-OFF switch.
	The grinder tends to produce a lot of torque and can get away from diver easily.	Should possibly be heavier.
	Torque from the tool tends to throw diver away from work object.	Add weight.
	--	Diver needs more weight.
	--	Provide a better chuck key.
Pump and cutters	It is easier to use the pump in the kneeling rather than standing position.	--
	The pump linkage broke after 5 minutes use.	--
	It was difficult to get the cable cutter off the cut hose.	--
	The grinder keeps rotating for 2-3 seconds after releasing trigger.	--
	It is too hard to get the cutter blade back in position.	--
	Difficult to get cutters on re-bar cutter to release.	--

4.5.1 Diesel Hydraulic Power Unit, NAVSEA Model II

TABLE 4-10

OPERATIONAL DATA OF POWER SUPPLY

Unit	Hours Operated	Atmospheric Temperatures			Total Failures	Mean Time to Repair (Hours)	Mean Time to Troubleshoot (Hours)
		High	Low	Mean			
CEL	40	100	50	70	2	2.5	5
HCU-I	104	90	70	80	0	-	-
NSCDS	200	90	70	80	5	1	1
NSRF	40	80	-	-	-	-	-
NSSF	40	90	10	55	1	3.0	-
UCT I	60	85	65	75	0	-	-
SDG I	33	80	55	65	2	0.5	0.2

TABLE 4-11

SAFETY RATING OF POWER SUPPLY

Unit	Very Safe	Safe	Marginal	Unsafe
CEL	X			
HCU-I	X			
NSCDS		X		
NSRF		X		
NSSF		X		
UCT I	X			
SDG I	X			

(Text Continued on Page 51)

TABLE 4-12

POWER SUPPLY FUNCTION OR COMPONENT RATING (S = Satisfactory, U = Unsatisfactory)

Function or Item	CEL	HCU I	NSDS	NSCDS	NSRF	NSSF	UCT I	SDG I
Engine starting	S	S	-	S	-	S	S	S
Hydraulic flow and pressure controls	S	U	U	U	S	U	S	S
Connection of hydraulic hoses	S	S	S	S	S	U	U	S
Hydraulic fluid temperature during operation	S	U	U	-	S	S	S	S
Fuel supply capacity	S	S	S	S	S	S	S	S
Handling of unit ashore	S	S	S	-	S	S	S	S
Handling of unit aboard ship	S	S	-	-	S	S	S	S
Adequacy of technical manual								
Operational Instructions	S	U	-	S	S	S	S	S
Troubleshooting	S	U	-	S	S	S	S	-
Scheduled maint. procedures	S	U	-	S	S	S	-	S
Corrective maint. procedures	U	U	-	S	S	S	S	-
Hydraulic oil reservoir	S	S	-	S	S	S	U	S
Adequacy of pressure and flowrate	S	S	-	S	S	S	S	S
Parts list	U	U	-	S	S	S	S	S
Performance of scheduled maint.	S	U	-	S	S	S	S	S
Performance of troubleshooting	S	U	-	S	S	S	S	S
Performance of corrective maint.	U	U	-	S	S	S	S	S
Availability of spare parts	S	U	-	S	U	-	S	-
Readability of gauges	S	S	-	S	S	S	S	S
Readability of labels	S	S	-	S	S	S	S	S
Generated noise level	S	U	-	U	S	S	S	S
Generated exhaust gas	S	S	-	S	S	S	S	S
Adequacy of furnished training	S	U	-	-	S	S	S	S
Adequacy of on-the-job training	S	-	-	S	S	S	S	S
General	-	-	-	-	S	-	-	-
Paint and material	S	S	-	S	U	S	S	S
Effects of heat and cold	S	S	-	S	S	S	S	S

4.5.2 Impact Wrench, Stanley, Model IW06

TABLE 4-13

OPERATIONAL DATA OF IMPACT WRENCH 6HS

Unit	Hours Operated Underwater	Total Failures	Mean Time to Repair (Hours)	Mean Time to Troubleshoot (Hours)
CEL	5	0	-	-
HCU-I	120	1	½	½
NSDS	60	0	-	-
NSCSD	150	0	-	-
NSRF	20	0	-	-
SDG I	4	0	-	-

Description of any accidents, near accidents or safety problems.

CEL None.

SDG I None.

TABLE 4-14

SAFETY RATING OF IMPACT WRENCH

Unit	Very Safe	Safe	Marginal	Unsafe
CEL	X			
HCU-I	X			
NSDS	X			
NSCSD		X		
NSRF		X		
SDG I	X			

TABLE 4-15

IMPACT WRENCH, STANLEY MODEL IW06 FUNCTION OR COMPONENT RATING
(S = Satisfactory, U = Unsatisfactory)

Function or Item	CEL	HCU I	NSDS	SNCDS	NSRF	SDG I
Use in drilling	S	S	S	S	S	S
Use as a power screwdriver	-	-	-	-	U	S
Tightening or loosening bolts	S	-	-	S	S	S
Removal and replacement of sockets	S	S	U	S	S	S
Removal and replacement of drill bits	S	U	S	S	S	S
Adequacy of chuck and key	S	S	S	S	U	S
Operation of trigger	S	S	S	S	S	S
Operation of reverse control	S	S	S	S	S	S
Adequacy of produced torque	S	S	S	S	S	S
Hydraulic hoses	S	S	S	S	S	S
Weight of tool underwater	S	S	S	S	S	S
Transportability of tool underwater	S	S	S	S	S	S
Tool handling underwater	S	S	S	S	S	S
Hose drag and weight underwater	S	S	U	-	S	S
Performance of preventive maintenance	S	S	S	S	S	S
Performance of corrective maintenance	S	S	S	S	S	-
Availability of spare parts	S	U	-	S	S	-
Furnished instruction	-	U	S	S	S	S
Paint and material	S	S	-	S	S	S
Effects of heat and cold	S	S	-	S	S	S

Description of any design or operational recommendations which should be incorporated.

HCU-1	Use tapered shank drill bits and chuck to increase ease of changing drill bits.

Approximately greatest depth at which tool was used.

Navy Unit	Depth (ft)
CEL	30
HCU-I	80
NSDS	10
NSCDS	35
NSRF	100
SDG 1	150

Approximately greatest current encountered when tool was used.

Navy Unit	Current (knots)
CEL	1
HCU-I	1
NSCDS	½
NSRF	½
SDG I	½

Maintenance manual recommendations as to extent of requirements.

Navy Unit	Recommendation
CEL	The four page manual provided by Stanley, is adequate for everything except the motor and that can be covered in three or four pages.
HCU-I	We need as much information as possible as the equipment is often used by individuals with little experience.
NSRF	The usual and common sense.
SDG I	A couple of pages with a parts list, PMS required and a cutaway drawing of operation.

Operations manual recommendations as to extent of requirements.

Navy Unit	Recommendation
CEL	Just safety information and techniques required for drilling to prevent damage to drill bits.
HCU-I	As complete as possible.
NSRF	The usual.
SDG I	A couple of paragraphs.

4.5.3 Impact Wrench, Stanley Model IW13

This tool has only been used by the Naval Ship Repair Facility, Subic Bay, and Harbor Clearance Unit I, Pearl Harbor. Their comments are essentially the same as for the Model IW06 impact wrench and will not be repeated.

4.5.4 Grinder, Stanley, Model GR24

TABLE 4-16

OPERATIONAL DATA FOR STANELY GRINDER

Naval Unit	Safety Rating	Hours Operated Underwater	Greatest Depth	Greatest Current	Total Failures	Mean Time to Repair (Hours)	Mean Time to Troubleshoot (Hours)
HCU-I	Very Safe	30	15'	½ kt	0	-	-
NSDS	-	30	10'	-	0	-	-
NSCDS	Safe	50	30'	½ kt	0	-	-
NSRF	Safe	5	30'	1 kt	0	-	-
SDG I	Very Safe	8	150'	½ kt	1	0.3	-

(Text Continued on Page 54)

TABLE 4-17

STANLEY GRINDER, FUNCTION OR COMPONENT RATING
(S = Satisfactory, U = Unsatisfactory)

Function or Item	HCU I	NSDS	NSCDS	NSRF	SDG I
Use in grinding	S	S	S	S	S
Use in wire brushing	S	-	S	S	S
Removal and replacement of grinding wheels	S	S	S	S	S
Operation of trigger	S	S	S	S	S
Adequacy of produced torque	S	S	S	S	S
Diver force required to hold grinder in place	S	S	S	S	S
Underwater weight of tool	S	S	S	S	S
Transportability of tool underwater	S	S	-	S	S
Tool handling underwater	S	S	S	S	S
Hose drag and weight underwater	S	S	S	S	S
Performance of preventive maint.	S	S	S	S	S
Performance of corrective maint.	S	S	S	S	S
Availability of spare parts	U	-	S	S	-
Furnished instruction	U	S	S	S	S
Paint & material	S	S	-	S	S
Effects of heat and cold	S	-	S	S	S

Briefly describe any problems you have had with tool or accessories not previously mentioned:

NSRF The shaft to which wheels are attached rusts easily.

SDG I The only trouble was a ruptured hose. We cut the hose back and used the same connection.

Briefly describe how extensive a manual is required for operating the tool:

HCU-I All manuals are necessary.

NSDS The manual is outstanding.

NSRF Normal operating manual and common sense.

SDG I A couple of paragraphs.

Briefly describe how extensive a manual is required for maintaining the tool:

HCU-I All manuals are necessary.

NSDS The breakdown of tools significantly simplifies maintenance.

NSRF Disassembly and reassembly, spare parts list.

SDG I A parts list, PMS required and cutaway drawing.

SECTION 5

TOOL PROBLEM, RECOMMENDATION AND ACTION SUMMARY

All of the evaluation identified problems and related recommendations have been reviewed.

The problems and recommendations considered most valid and significant have been listed; judgments have been made as to required action and action status has been listed, Table 5-1.

(Text Continued on Page 57)

TABLE 5-1

TOOL PROBLEMS, RECOMMENDATIONS AND ACTION

Tool	Identified Problem	Diver-Evaluator Recommendation	NCSL Recommendation	Action
Diesel Hydraulic Power Supply	Overheating of hydraulic oil in warm climates.	Use cooling system.	Replace constant flow pump with a variable displacement piston pump.	C
	Unit too large and heavy for use on some work boats.		Provide additional lightweight power supply.	C
	Controls not located for operator convenience.	Mount controls on front panels.		N
	Operation and maintenance manuals inadequate.		Prepare manuals.	C
	Inadequate muffler system.			N
	Flow meter lacks accuracy.		Replace with improved meter.	C
	Fuel tanks difficult to remove.		Modify to permit removal from bottom of unit.	C
	Provide unit with a fuel dip stick.		Fill pipe modified so you can see fuel level.	C
	No cold weather evaluation done.		Should be done.	P
Hydraulic Impact Wrench	Drill chucks become become jammed after considerable impacting.		Provide proper instructions.	C
			Design adapter to prevent over tightening and evaluate.	P
			Evaluate adequacy of impact type chuck versus Jacobs chuck.	P

Tool	Identified Problem	Diver-Evaluator Recommendation	NCSL Recommendation	Action
	Inadequate operation and maintenance instructions.		Prepare manuals.	C
Hydraulic Grinder	Guard traps water and produces excess torque for diver to counter.		Remove guard for U/W use.	C
	Lacks adequate torque.		Use 3/4" dia. hydraulic hose and 1/2" dia. wip. (Smaller hose was restricting flow).	C
	Grinding disks shattered in use.		Use "Pacific" grinding wheels or equivalent.	C
	Grinder develops too much torque for some divers.		Divers should wear more weight while using tool and remove guard.	N
	Inadequate operation and maintenance manuals.		Prepare manuals.	C
Diver Operated Pump and Cutters	Base and handle inadequate.		Redesign	C
	Pump handle linkage failed.		Redesign	C
	Difficult to get cutters to retract.			N
Sump/Jetting Pump	Provide more power or output.	Increase pressure.		N
Hydraulic Hoses	Hoses are too negative.	Use Synflex hose.		N
Hydraulic Hose Connections	Misc. problems due to corrosion, quick disconnect coming loose and confusing hoses.	Use CRES fittings, screw type disconnects and fool proof hose connections.	Place a hose clamp back of the female half of the quick disconnect.	P

Action Code: C = Completed or in work; P = Planned (Funding required); N = Not planned.

SECTION 6

COMPLETED TOOL MODIFICATION

All major tools developed or modified by NCSL are included in this section, although some of the tools have received only preliminary evaluation and are not presently recommended for "authorized for Navy use" without further T&E. All of the tools are considered to be of significant value to the Navy diver. Funds for evaluation will be requested in order that approval for Navy procurement may be obtained for all effective tools.

Diesel Hydraulic Power Supply. Modifications to the NAVSHIPS Model 1, have been described in Section 4.2.1.

Portable Hydraulic Power Unit. (Designed and fabricated by NCSL). Modifications have been completed following informal testing of the early prototype model as follows:

1. One of the rubber tired wheels has been relocated to add stability, and hinged to permit rapid change from the fixed to the mobile mode.

2. Rubber leg pads have been added to reduce running vibration and movement.

3. Lift screw eye and attachment points have been added for hoisting.

4. The internal frame has been redesigned to reduce fatigue failures.

5. The plumbing has been simplified.

6. An improved temperature gauge has been substituted.

7. Drawings have been updated.

Hydraulic Flow Divider. The aluminum frame was enlarged to provide clearance for operating the control handle and for ease of hand carrying. A flow meter was added and the plumbing simplified.

Hydraulic Come-a-long. Hydraulic valves were added to permit underwater control. The fittings were changed from British metric to SAE.

Hurst Rescue Tool. The internal seals have been replaced to be compatible with petroleum base hydraulic fluid as required. Flotation devices have been designed and preliminary informal testing accomplished.

Hydraulic Abrasive Wheel Saw. Informal in-house lists were completed to evaluate the original configuration. The tool has been redesigned to provide greater strength and to simplify construction.

Diver Operated Pump. The base and handle were redesigned to provide greater ease of operation by the divers. The reversing block was modified to prevent it from working loose during prolonged use.

Flow Divider. The aluminum frame was redesigned to provide for greater clearance for control valve operation and for a hand-hold. A flow meter was added to permit more accurate control of flow to each tool.

Hydraulic Intensifier. The hydraulic fittings were modified to provide greater protection against handling damage. An improved flow limiting valve was substituted.

Lift Bag (SUPDIV) 750 lb. Handles were added to improve diver handling and transport underwater and the sling lengths were increased.

Rock Drill Kit (Pneumatic). The system was modified to permit using a scuba cylinder as the air supply. A tube was added to remove the exhaust air from the tool to reduce obstructing the divers vision and to reduce excessive noise.

Hydraulic Cutters and Self Contained Jack/Ram. The tools have been modified by coating the inside and outside of the cylinder and the piston with molybdenum disulphide and black oxide to reduce water intrusion caused corrosion.

SECTION 7

DRAWINGS, MANUALS, AND PARTS LISTS STATUS

The complete and current status of all design drawings, manuals and parts lists are shown in Table 7-1.

(Text Continued on Page 60)

TABLE 7-1

DRAWINGS, MANUALS AND COMPONENTS LIST STATUS

Tool	Status			
		Manual		
	Design Drawings	Operational	Maintenance	Component List
1. Diesel Hydraulic Power Supply NAVSEA, Model II	C	CP	CP	C
2. Hydraulic Grinder, Model GR 24	C	BA	BA	C
3. Hydraulic Impact Wrench, Model IW13	R	BA	BA	C
4. Hydraulic Impact Wrench, Model IW06	C	BA	BA	C
5. Hydraulic Abrasive Wheel Saw (NCSL)	C	BA	BA	C
6. Sump/Jetting Pump, Stanley, Model SM 22	C	R	R	C
7. Hydraulic Come-a-Long, Griphoist, TU17H	C	CNI	CNI	C
8. Hurst Rescue Tool, Hurst Performance	IW (95)	R	R	R
9. Flow Divider, Fluid Controls/NCSL	C	R	R	C
10. Diver Operated Pump, Enerpac/NCSL	C	BA	BA	C
11. Barstock Cutter, H. K. Porter	N/R	BA	BA	C
12. Single Acting Jack Rams, Enerpac	N/R	BA	BA	C
13. Hydraulic Pull Cylinder, Misc. Suppliers	C	BA	BA	C
14. Hydraulic Intensifier, NCSL	C	BA	BA	C
15. Lift Bag, (SUPDIV) 750 lb	IW (95)	IW (60)	IW (60)	IW (95)
16. Portable Hydraulic Power Unit, NCSL	C	IW (80)	IW (80)	C
17. Rock Drill Kit, Pneumatic Tool Sales/NCSL	R	IW (60)	IW (60)	IW (90)

Status Abbreviations:

C = Completed
IW = In Work (Percent complete shown)
R = Required but not in work
NR = Not required
CP = Currently being printed
BA = Currently being assembled in camera ready form
CNI = Completed but not included in current manual

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

1. The following tools have been subjected to substantial evaluation and are considered to be satisfactory for Navy use.

Hydraulic Power Supply, NAVSEA, Model II
Hydraulic Grinder, Stanley, Model GR24
Hydraulic Impact Wrench, Stanley, Model 1W06
Hydraulic Impact Wrench, Stanley, Model 1W13
Sump/Jetting Pump, Stanley, Model 2250H-OC
Diver Operated Pump, Enerpac/NCSL P80 (Modified)
Barstock Cutter, H. K. Porter, Model 36274
Wire Rope Cutter, H. K. Porter, Model 36262
Lift Bag, SUPDIV, 750 lb.

2. These tools have been subjected to preliminary evaluation at NCSL. Fleet evaluation and data collection has not been accomplished.

Hydraulic Abrasive Wheel Saw, NCSL
Come-a-Long, Griphoist, Model TU28H and TU17H
Hurst Rescue Tool, 6 ton capacity, Hurst Performance
Flow Divider, Fluid Controls/NCSL
Single Acting Jack Rams, Enerpac, Model RC 106 and RC 1010
Hydraulic Pull Cylinder, Misc. Suppliers
Intensifier, Hydraulic, NCSL
Hydraulic Portable Power Source, NCSL
Rock Drill Kit, Pneumatic Tool Sales/NCSL
Torque Limiter, 4X Corporation

These tools should be procured and issued to Navy Diving Groups for additional use and evaluation, as was done with the tools issued in the Navy Diver Tool Kits. The Navy diving groups should be required to complete such evaluation without delay, and NCSL should be responsible for the preparation, administration, and evaluation of questionnaires prepared for the test and evaluation phase.

3. All tools listed in both of the above groups should undergo cold water testing.

4. Not all required drawings, manuals, and components lists have been completed as shown in Table 7-1. NCSL should complete this work.

SECTION 9

REFERENCES
(Annotated)

1. Naval Civil Engineering Laboratory Technical Report R-653, *Diver Performance Using Hnad-tools and Hand-held Pneumatic Tools,* by F. B. Barrett and J. Quirk, December 1969, Unclassified.

The Naval Civil Engineering Laboratory, Port Hueneme, and the Naval Missile Center, Point Mugu, California, have jointly conducted tests to measure diver performance using handtools and hand-held pneumatic tools. The tools included adjustable pipe and machine wrenches, ratchet and special hand wrenches, screwdrivers and the following pneumatic tools: two drills, a power saw, an impact wrench, and a chipper. The initial tests were conducted on land and in a test tank filled with fresh water. Ocean tests using the same tools were accomplished at a working depth of 50 feet. Performance times of divers using the various tools on vertical, deck, and overhead surfaces in the ocean are reported. Performance decrements for in-tank and ocean tests are compared to land-test performance. Difficulties encountered using the various tools, tethering devices, and tool holding and transporting devices are reported and suggestions for improvement are made where applicable. Additional tests conducted in the ocean to determine diver one- and two-arm strength while working on vertical, deck, and overhead surfaces are summarized in the appendix.

2. Naval Civil Engineering Laboratory Technical Report R-729, *Technical Evaluation of Diver-Held Power Tools,* by S. A. Black and F. B. Barrett, June 1971, Unclassified.

Pneumatic and hydraulic hand-held power tools were evaluated by divers performing realistic underwater tasks. These tasks included drilling steel and aluminum, nut running and tightening, grinding metal, and chain sawing wood. An on-the-site observer monitored diver performance time for each task. Diver skill in effective tool utilization is very important in working underwater. At test depths to 60 feet, hydraulic tools were very effective and practical, while pneumatic tools, although effective, required excessive maintenance. At greater depths, hydraulic tools retain their effectiveness, but pneumatic tools lose effectiveness because of the compressibility of gas. Hydraulic tools generally supply more energy per unit of tool weight than do pneumatic tools; thus, the diver can perform work more rapidly using hydraulic tools.

3. Naval Civil Engineering Laboratory Technical Note N-1145, *Underwater Work Functions Required in Salvage,* by G. L. Liffick, February 1971, Unclassified.

Sixteen past salvage operations have been reviewed and two experienced salvors interviewed to determine the work functions required in underwater salvage. The results indicate seven work functions are compatible with hydraulic systems. These work functions are: rigging and load handling, bolting, mechanical cutting, tunneling/excavating, grappling, drilling and tapping.

4. Naval Civil Engineering Laboratory Technical Note N-1229, *Hydraulic Tools and Equipment for Underwater Salvage,* by G. L. Liffick and F. B. Barrett, July 1972, Unclassified.

Extending the U.S. Navy's underwater salvage capability will require improved diver-operated tools and equipment. NCEL (Naval Civil Engineering Laboratory) is conducting a program to develop hydraulic hardware for future underwater salvage operations. Commercially available hydraulic pumps, rigging, load handling and cutting equipment have been evaluated at NCEL to determine characteristic diver performance and mechanical suitability for underwater operation. Manually operated hydraulic pumps were modified and pumped against a load cell to determine reasonable levels of diver exertion. Tests have shown that divers can be utilized as prime movers for small jobs and that some conventional surface hydraulic equipment can be used underwater for reasonable periods of time with a minimum of additional maintenance. Surface hydraulic equipment suitable for underwater operation includes manual pumps, rams, cylinders and several cutters. However, innovative new equipment is urgently required for underwater salvage, particularly for load handling.

5. Naval Civil Engineering Laboratory Technical Report R-684, *Salvage Work Projects - SEALAB III,* by J. J. Bayles, June 1970, Unclassified.

The Navy is authorized by public statute to provide salvage facilities to assist both public and private vessels. In keeping with this responsibility the Supervisor of Salvage, U.S. Navy, is prosecuting a vigorous program to incorporate the latest techniques and equipments into the Navy's salvage forces.

The SEALAB III program, under the direction of the Ocean Engineering Branch, Deep Submergence Systems Project Office, was initiated to advance the state-of-the-art of man's capability to live and work in the deep ocean environment. It was the goal of the Salvage Projects for SEALAB III to demonstrate and field test some of the more important new salvage devices and techniques.

This report discussed the aquanaut familiarization and training phase associated with the Salvage Projects planned for Team Two— SEALAB III and the modifications to both equipments and procedures as suggested by the divers. Preliminary results are included with recommendations regarding future plans.

Human factors studies were conducted in conjunction with the training phases in preparation for SEALAB III. Goals included assessment of divers performance, the development of improved underwater work procedures, and improvement of underwater equipment design through development of design criteria.

6. Naval Civil Engineering Laboratory Technical Note N-1174, *Submersible Diver Tool Power Sources; Electrohydraulic and Cryogenic Pneumatic,* by S. A. Black, August 1971, Unclassified.

Two self-contained and completely submersible power supplies for powering diver operated hand-held tools are discussed; one power supply operates pneumatic tools while the other operates closed cycle oil hydraulic tools. Operational evaluations performed with Navy qualified divers using hand-held tools powered by the modules proved both to be effective submersible power sources. Refinements necessary are delineated.

7. Naval Civil Engineering Laboratory Technical Report R-801, *Design Criteria for Power Sources Supplying Underwater Hydraulic Tools,* by G. L. Liffick, S. A. Black and J. Mittleman, December 1973, Unclassified.

The Naval Civil Engineering Laboratory is developing hydraulic power sources for underwater hydraulic tools. Hydraulic power sources driven by diesel and gasoline engines and electric motors have been successfully developed and evaluated. The operational testing was conducted by divers utilizing hydraulic tools to work underwater. The criteria for selecting a particular hydraulic circuit and the components for an underwater hydraulic power source are different from those used for designing a hydraulic power source for surface tools. For example, a hydraulic pump's tolerance for salt water and its reliability are generally more important than the pump's volumetric efficiency. Pressure and flow gauges must be able to withstand severe mechanical vibration, hydraulic fluid shock, and salt spray corrosion. Hydraulic hose expansion under pressure must be minimized but not at the expense of excessive weight. Hydraulic hose couplings should be easy to couple and uncouple but should not separate when dragged over the side of a boat. Hydraulic fluid must provide adequate lubricity, have a low viscosity in cold water and retard damage to the hydraulic system from intruding salt water. The appraisal given in the report of the relative merits of different hydraulic circuits and components is based on

experience gained during NCEL's power source evaluation program. Final component selection, however, is dependent on the user's particular requirements.

8. Liffick, G. L., Mittleman, J., and Quirk, J., *Diver Tools*, presented at the Symposium Proceedings, "The Working Diver," Columbus, Ohio, March 5-6, 1974.

The Supervisor of Salvage has recently provided hydraulic diver tool sets to fleet activities. This paper describes the equipment provided, training program, and the early work experience. Also covered is recent Navy experience in sonar dome cleaning including a description of hydraulic powered and pneumatic power systems with a brief discussion of brush design.

9. Naval Ship Systems Command, *Proceedings of the Underwater Ship Husbandry Workshop*, by R. E. Elliott, J. Mittleman and J. Quirk, January 1975, Washington, D. C., September 1975, SUPDIV Report 4-75, Unclassified.

Underwater Ship Husbandry encompasses repair, maintenance, and inspection tasks performed by divers as a service to waterborne ships. In our Navy the execution of these tasks is primarily the responsibility of shipyard, tender, and repair ship diving crews. The Supervisor of Diving (SUPDIVE) funds and monitors research and development efforts whose objectives are to upgrade the capabilities of ship husbandry divers through hardware developments and information transfer. The Naval Coastal Systems Laboratory (NCSL), in Panama City, Florida, is the prime laboratory performing ship husbandry R&D for SUPDIVE.

On January 7 and 8, 1975, NCSL hosted the first Navy-wide Underwater Ship Husbandry Workshop, sponsored by SUPDIVE. Representatives from NAVSEA, shipyards, tenders, repair ships, ship repair facilities, and laboratories participated in two intensive days of group discussions and presentations. The aims of the Workshop, which were successfully accomplished, were:

- Familiarize the workshop participants with the scope and nature of underwater ship husbandry work performed by each represented activity.

- Document the state-of-the-art in each of the nine task areas:

  1. Tools.
  2. Hull and dome cleaning.
  3. Propeller changing.
  4. Underwater paints and adhesives.
  5. Shallow water dive gear and inspection systems.
  6. Submarine work and ship design changes.
  7. Zinc changing, blanks, and cofferdams.
  8. Underwater welding.
  9. Shipyard diving.

- Suggest technological and managerial improvements in each task area.

- Educate workshop participants through group discussions and through demonstrations of recently developed hardware.

Highlights of the Underwater Ship Husbandry Workshop are presented.

10. Naval Ship Systems Command Technical Manual NAVSHIPS 0994-013-1010, *Diesel Hydraulic Power Unit, NAVSHIPS Model 1, Operation of Maintenance Instructions,* October 1973.

The manual contains information for operating and maintaining the Model 1, Diesel Hydraulic Unit as a source of power to drive open-center type hydraulic power tools, primarily those used underwater.

11. Naval Medical Research Institute Report No. 7, NMRI Project M4306.03.2040DAC9, *Comparative Human Factors Analysis of the U.S. Navy Mark V and Mark XII Dive Systems,* by F. W. Armstrong, et al., June 1974.

A series of tests were conducted to assess the suitability of the U.S. Navy prototype Mark XII hardhat diving system as a replacement for the U.S. Navy standard Mark V diving system. The tests combined operational testing with human engineering and human factors testing to depths of 300 feet under four separate environmental conditions: open tank, hyperbaric chamber, Anacostia River, and open water. Air was used as the breathing medium for shallow depths, with HeO_2 substituted as depths increased. Task times were recorded and compared, as well as dressing and undressing times. An equipment evaluation was made by each diver on the Mark XII. Salvage tools and tasks used in the evaluation were developed by the Naval Civil Engineering Laboratory, Port Hueneme, California. In addition to the field evaluations, an anthropometric study of both systems was performed, measuring range of movements on 14 anthropometric measures.

12. Naval Experimental Diving Unit Interim Report No. 7-74, *Technical Evaluation of the Surface Supported Diving System, USN Mark XII,* by D. R. Chandler, 1974.

The Surface Supported Diving System, USN MK XII was developed in response to the requirement for improving the equipment of the U.S. Navy hardhat diver.

The first part of the evaluation considered the technical adequacy of the system and included physiological studies, gas flow and acoustic studies, and representative salvage task studies. The second part of the evaluation, the operational phase, considered such factors as reliability, maintainability, compatibility, and supportability. The basic evaluation approach was to dive the system in a wide range of conditions utilizing active duty Navy divers, so that the system developed for use by divers could be evaluated by divers.

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